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Adnotanda in fungos aliquot exoticos regii Musei lugdunensis.

Auctore Ab. J. Bresadola.

Clar. Dr. J. G. Goethart, regii Musei lugdunensis director egregius, mihi anno praeterlapso collectiones exoticas nondum determinatas hujus Musei, nec non specimina plurima originalia Junghuhnii, Leveillei etc. determinandi vel consulendi causa benevole misit.

E studio horum speciminum, quod nuper absolvi, ea quae ad meliorem cognitionem specierum nondum rite cognitarum deserviunt, excerpi et simul cum diagnosibus specierum novarum in sequentibus plagulis depromam.

Tridenti, Julio 1910. Ab. G. Bresadola.

Polyporus obovatus Jungh. Crypt. Jav. p. 65 n. 31 est *Polystictus* sp. ***Polystictus obovatus*** dicendus. Syn. *Polystictus lacer* Jungh. l. c. no. 32. *Polyporus Adami* Berk. in Cooke Enum. Polyp. in Grev. XIV, p. 137! *Polyporus rasipes* Berk. Challeng. no. 241!

Polyporus umbilicatus Jungh. l. c. p. 72. A *Polyporo arculario* diversus. Sporae cylindraceo-subcurvulae, 6—7 ⩽ 2½—3 μ; hyphae hymenii 2—3½ μ; hyphae pilei 1½—4½ interdum hic illic inflatae, ibique 9—15 μ latae.

In *Polyporo arculario* sporae 7—9 ⩽ 2½—3 μ; hyphae hymenii 2—4, una alterave —6 μ; hyphae pilei 1½—7 μ raro inflatae ibique —10 μ latae.

Polyporus cinerescens Lév. Champ. exot. p. 184 (1844). Syn. *Polyporus incurvus* Cooke Grev. XIV! *Polyporus flabellato-lobatus* P. Henn. Engl. Jahrb. 1898 XXV, p. 500!

Polyporus indecorus Jungh. l. c. p. 51 est = *Polyporus corrugatus* Pers. (1826) Gaud. Voy. Freye. Bot. p. 172.

Polyporus floccosus Jungh. l. c. p. 49. Videtur *Polyporus gibberulosus* Lév., sed hyphae contextus tam hymenii quam pilei majores et pori minores. Hyphae hymenii 1½—4½ μ, pilei 1½—6½; pori ⅕—¼ mm.

Polyporus Mons-Veneris Jungh. l. c. p. 61. *Polyporus funalis* Fr. differt modo colore minus fulvus. An satis?

Polyporus cervino-gilvus Jungh. l. c. p. 45. Syn. *Polyporus dermatodes* Lév. Bon. 180, *Hexagonia vitellina* Cesati Myc. Born. p. 8! *Polyporus Peradeniae* Berk. et Br. Journ. Linn. Soc. XIV, p. 51 (1875).

Polyporus tropicus Jungh. l. c. p. 63 est *Ganoderma* sp. ***Ganoderma tropicum*** dicendus.

Sporae fuscidulae, obovato-truncatae, episporio asperulo, 10—12⩽7—9 μ; hyphae hymenii $1^1/_2$—4 μ, pilei $1^1/_2$—6, saepe tortuosae. — Species haec certe aliunde descripta, sed synonyma mihi ignota.

Polyporus flavus Jungh. l. c. p. 46 est *Irpex* sp., omnino = *Irpex flavus* Kl. Linnaea, VIII, p. 488! (1833).

Polyporus splendens Lév. Champ. Mus., p. 187, valde est *Polypor. pavonio* (Hook.) Fr. proximus, sed non identicus. Pileus vix zonatus, nec zonis glabris, dissepimenta tubulorum tenuiora etc. attamen ceu varietas considerari potest.

Polyporus bicolor Jungh. l. c. p. 54 (1838) est forma tenuior *Polyporí sanguinarii* Kl. (1833). *Polyporus anebus* Berk. est prorsus identicus prouti e speciminibus Musei Kewensis patet. Variat pileo postice fuco-rubro vel concolore. Insuper sunt quoque synonyma: *Polyporus pruinatus* Berk. et Kl.! *Polyporus vulneratus* Lév.! *Polyporus anisopilus* Lév.! *Fomes polytropus* Berk. et Br.! *Hapalopilus subrubidus* Mur.! *Polystictus subpictilis* P. Henn. Insuper nec *Fomes*, sed *Polyporus*.

Polyporus loricatus Pers. Myc. Eur. II, p. 86 est prorsus, bene observante Fries = *Fomes salicinus* Pers. vetustus, poris aetate canescenti-cinereis.

Polyporus placopus Lév. Champ. Mus. p. 124 est, uti jam cognitum fuit, *Ganoderma* sp.

Pileus 6—20 cm latus, 4—6 cm longus, laccato-lucidus, niger; stipes 12—24 cm longus, 8—12 mm crassus, concolor et lucidus; sporae fuscidulae, echinulatae, 12—13⩽8—9 μ; hyphae hymenii $1^1/_2$—$4^1/_2$ raro 5 μ.

Polyporus Cochlear Blume et Nees, Nova Acta Acad. Caes. Leop. III, p. 20 tab. VI est *Ganoderma*, uti jam notatum fuit, sed, meo sensu, a *Ganoderma amboinense* specifice distinctum. Jam forma magis cochleata, color generati mopacior, raro sublucidus, substantia pallidior; sporae majores, sc. 12—15⩽7—9 μ laeves vel sublaeves et hyphae hymenii vix aculeatae.

Polyporus rugosus Blume et Nees l. c. p. 21 tav. VII est *Ganoderma (Amauroderma)* sp. Sporae subglobosae, 11—12⩽10—11 μ, fuscidulae vel pallidae; hyphae hymenii crassae, 2—6 μ; pilei irregulares, 2—6 μ crasse tunicatae.

Polyporus auriculiformis Jungh. Ann. Sc. nat. 1844 p. 194 non est *Poria*, sed *Polyporus* vix diversus a *Pol. gilvo* Schw. sc. forma ad *Polyporum licnoidem* Mont. transiens.

Poria Pellicula Jungh. l. c. p. 44 est *Irpex* sp. habitu prorsus *Irpicis flavae* (Jungh.) Kl., sed colore et structura optime diversus. Diagnosis magis congruam damus: **Irpex Pellicula** (Jungh.) Bres.

Pileo effuso breviterque reflexo, tomentoso, spongioso-molli, extus intusque albo, laeviter sulcato-zonato, 5—9 cm lato, 2 cm reflexo; dentibus spathulatis, basi poroso-sinuosa suffultis, primitus alutaceis, dein fuscis,

ex hyphis hyalinis, 3—7 μ, crassis, apice liberis, obtusis, fuscidulis, 4—5 μ, extus pruinosis; hyphis pilei 4—6 μ crasse tunicatis; basidia nondum generata.

Specimen Junghuhnii mancum, sed specimina completa ex Timor misit cl. Prof. C. Torrend, at ista quoque sterilia.

Poria roseo-alba Jungh. l. c. p. 43 est *Fomes* sp. ***Fomes roseo-albus*** dicendus. Est forma resupinata, margine breviter vel vix reflexa. Synonyma: *Fomes mortuosus* Fr. Nov. Symb. Myc. p. 64 (1851)! *Fomes caliginosus* Berk. Chall. Exp. no. 209 (1878)! *Coriolopsis Copelandii* Murrill Bull. Torrey Club, 35, 1908, p. 392!

Trametes Perrottetii Lév. Champ. exot. p. 195 (1844). Synonymon: *Polyporus trichomallus* Berk. et Mont. Cent. VI, no. 65 (1849).

Daedalea microzona Lév. Champ. Mus. p. 142 (1846) est forma bene evoluta *Daedaleae flavidae* Lév. Champ. exot. p. 198 (1844)! Structura quoque identica! Contextus hymenii ex hyphis 1—4½ μ, pilei 1—5 raro 5½. Etiam *Polyporus lenziteus* Lév. Zollinger Pl. Jav. no. 732 huc ducendus.

Species haec bene evoluta usque ad 20 cm lata hymenio valde variabili, ut plurimum polyporoideo hinc illic lenzitoideo. *Daedalea lurida* Lév. videtur varietas.

Merulius affinis Jungh. l. c. p. 76 est *Hirneola* sp., ***Hirneola affinis*** dicenda. Synonymon: *Laschia velutina* Lév. typus ex Java, non ex Brasilia.

Pili receptaculi fasciculati, straminei, 50—120⩽7—12 μ basi; sporae hyalinae, cylindraceo-curvulae, 10—12 ⩽ 4½—5½ μ; basidia clavata, 35—40⩽5—6; hyphae contextus intricatae, 1½ μ crassae. Ab *Hirneola delicata* (Fr.) Bres. differt colore hyalino-substramineo, pilis latioribus et sporis brevioribus.

Merulius cucullatus Jungh. l. c. p. 76 est *Laschia* sp., ***Laschia cucullata*** dicenda.

Sporae hyalinae, subglobosae, vaculeolatae, 4—4½⩽3—3½ μ; basidia clavata 22—24⩽4—5 μ, hyphae subhymeniales 1—1½ μ. — *Laschia celebensis* Pat. valde proxima et forsan identica.

Laschia spathulata Jungh. l. c. p. 75 *(Hymonogramme spathulata* (Jungh.) Sacc. Syll. V, p. 653) est *Favolus* sp. ***Favolus spathulatus*** dicendus. In specimine originali pori ab insectis sunt corrosi, remanente tantum basi reticulata, at prope marginem adsunt quoque pori integri, oblongo-angulati, membranacei, prorsus *Favoli*. *Favolus moluccensis* Mont. Cent. IV, p. 83 videtur forma major, et vix dubie huc ducendus. Color, structura etc. concordant, modo pori magis rotundati.

Laschia crustacea Jungh. l. c. p. 75 est *Poria* sp., ***Poria crustacea*** dicenda. Pori tenues, saepe obliqui, membranacei non gelatinosi nec cartilaginei; hyphae contextus pororum 2—4 μ; sporae (?) 4⩽3 μ; cystidia tunicata, 20—30⩽6—9 μ, basi laevia, 4 μ crassa.

Thelephora (Stereum) villosa Lév. Champ. exot. p. 212 est *Hymenochaete* sp., ***Hymenochaete villosa*** dicenda. Setulae fulvae, 29—45 ⩽ 4—7 μ, hyphae contextus $2^1/_2$—4 raro 5 μ crassae. Ab *Hymenochaete nigricante* vix diversa.

Thelephora papyracea Jungh. l. c. p. 36 est *Lloydella* sp., ***Lloydella papyracea*** dicenda. Cystidia 90—120 ⩽ 7—12 μ; hyphae hymenii 2—6 μ.

Thelephora concolor Jungh. l. c. p. 38 est = *Thelephora ostrea* Blume et Nees, Nova Act. Acad. Caes. Leop. III, p. 13 tab. II, fig. 1 (1826) = *Thelephora lobata* Kunze in Wegelins exsicc. 1827.

Thelephora coccinea Jung. l. c. p. 36 est *Peniophora* sp., ***Peniophora coccinea*** dicenda. Cystidia hyalina, furfuraceo-tunicata, fusoideo-ventricosa, 40—50 ⩽ 9—10 μ; hyphae contextus conglutinatae, 2—4. Basidia et sporae non visae.

Polyporus Goethartii Bres. n. sp.

Pileo suberoso-lignoso, laterali, flabellato vel reniformi, glabro, subtuberculoso, plus minusve leviter sulcato-zonato, isabellino umbrino, 7—15 cm lato, 6—9 cm longo, $1^1/_2$—2 cm crasso; contextu flavo-ferrugineo, duro, interdum striis albis variegato, 10—12 mm crasso, ex hyphis $1^1/_2$—$4^1/_2$ μ crassis conflato; stipite laterali, brevi, toruloso, basi dilatata adnato, 5—12 mm longo, $1^1/_2$—3 cm lato, interdum obsoleto; tubulis umbrinis, $^1/_2$ cm longis; poris umbrino-fuscidulis, parvis, $^1/_7$ mm, subrotundis; hyphis hymenii 2—3 μ crassis; sporis non inventis.

Hab. ad truncos, Java. Junghuhn, no. 128, 129.

Obs. *Polyporo vallato* Berk. proximus videtur. Specimina omnia visa margine prolifero praedita, sc. ex parvis pileis transversim positis ita ut margo lobato-serrulatum appareat.

Fomes latissimus Bres. n. sp. (*Fomes ligneus* Murrill non Berk.).

Pileo latissimo, 20—36 cm lato, 12—24 cm longo, explanato, glabro, tuberculoso, concentrice sulcato, incrustato, cute fuscidula, 1 mm crassa, margine obtuso, saepe reflexo, postice interdum decurrente; contextu suberoso-lignoso, pallide alutaceo, ex hyphis $1^1/_2$—$3^1/_2$ μ crassis; tubulis stratosis, concoloribus; poris minutis, $^1/_7$—$^1/_6$ mm, dissepimentibus crassis, stramineis; sporis hyalinis, obovatis, 6—8 ⩽ $3^1/_2$—5 μ; basidiis clavatis, 18—20 ⩽ 4—5 μ; cystidiis fusoideo-ventricosis, 24—30 ⩽ 10—12 μ; hyphis hymenii $1^1/_2$—3 μ.

Hab. ad truncos. — Java.

Obs. Medius inter *Fom. hornodermum* Mont. et *Fom. hippopus* (Willd.). A *Fomite hornodermo*, cujus habitum habet, differt structura diversa, a *Fomite hippopo*, cujus habet structuram, differt habitu et praesentia cystidiorum. A *Fomite ligneo* Berk. prorsus diversus.

Fomes surinamensis Bres. n. sp.

Pileo ungulato, dense concentrice zonato subsulcato, postice decurrente, glabro, incrustato, cute nigra, sublucida in vetustis, $1^1/_2$ mm crassa, 7 cm vel ultra lato, 4 cm alto; substantia lignosa, fulva, 2—3 mm tantum

crassa, ex hyphis 2—3½ μ; tubulis stratosis, stratis vix visibilibus, fulvis; poris fuscidulis, parvis, ⅛—⅙ mm, subrotundis, dissepimentibus crassis; sporis stramineis, raris visis, 4—5 ⩽ 4 μ; hyphis hymenii 2—3½ μ.

Hab. ad ligna. — Surinam.

Obs. Variat resupinatus, tuncque formam pulvinatam accipit, etiam valde stratosam — *Fomiti roburneo* Fr. proximus.

Fomes subendothejus Bres. n. sp.

Pileo pulvinato, fasciis parvis, latis, prominentibus, praedito, stratis annuis luteolis et subvelutinis vel pruinatis, vetustis glabris, nigricantibus et cute diffracta, 12—14 cm lato, 7—8 cm longo, margine valde obtuso, toruloso; contextu lignoso-fibroso, luteo-fulvo, ex hyphis 2—5 μ crassis; tubulis concoloribus; poris fusco-umbrinis, irregularibus, angulatis, ¼—½ mm, vel oblongis ½—1 mm; sporis globosis, luteis, 5—6 μ diam.; hyphis hymenii 1½—3½ μ.

Hab. ad truncos — Curaçao.

Obs. Species haec *Fomiti endothejo* Berk. proxima et valde similis, sed substantia magis fulvella ex hyphis strictioribus conflata et poris duplo fere majoribus diversa.

Mycologische Fragmente[1]).

Von Prof. Dr. Franz v. Höhnel in Wien.

CXVIII. Über die Gattung Hyalodema.

Unter diesem Namen hat Paul Magnus jüngst einen Hyphomyceten beschrieben (Berichte d. deutsch. botan. Ges. 1910, 28. Bd., p. 377), der in Transvaal auf Zweigen von *Zizyphus* sp. krebsartige Anschwellungen veranlaßt. Die größeren dieser gallenartigen Bildungen stehen nach der Abbildung (l. c. Taf. XI, fig. 1) zu urteilen ziemlich regelmäßig an den Zweigen nahe der Basis der zweizeilig angeordneten kurzgestielten Blätter, etwa dort, wo sich an gesunden Zweigen die Früchte befinden. Es ist zu vermuten, daß wenigstens ein Teil der Auswüchse vom Pilze frühzeitig befallene Früchte sind. Dafür spricht auch nicht bloß der Umstand, daß diese Pilzgallen mit stark verschmälerter Basis aufsitzen, sondern insbesondere der, daß von dieser Basis zahlreiche Gefäßbündel in das Innere der Pilzgallen eintreten. Diese Bündel gehen natürlich nicht von der Basis der Pilzgallen aus, sie müssen mit dem Bündelring der Zweige in Verbindung stehen. Daher können die gallenartigen Bildungen nicht einfache Gewebewucherungen sein, sondern müssen aus eigenen morphologisch bestimmten Gliedern der Nährpflanze durch die frühzeitige Einwirkung des Pilzes entstanden sein.

Was nun den Pilz selbst anlangt, so kommen nach P. Magnus nur die beiden Gattungen *Synthetospora* Morgan und Sekt. II *Mystrosporella* Sacc. zum Vergleiche in Betracht. Allein von *Synthetospora* habe ich schon 1907 (Fragmente z. Mykologie III. Mitt. No. 155) angegeben, daß damit offenbar *Stephanoma* Wallr. identisch ist.

Neben *Mystrosporella* hätte auch *Stemphyliopsis* A. L. S. (Sacc. Syll. XVIII, p. 561), welche anscheinend parasitisch lebt, in Betracht gezogen werden sollen.

Aber abgesehen hiervon ist es sicher, daß *Coniodyctium* H. et Pat. (Bull. soc. mycol. 1909, XXV, p. 13, m. fig.) offenbar dieselbe Gattung darstellt wie *Hyalodema*. *Coniodyctium Chevalieri* H. et Pat. lebt in Afrika auf den Früchten von *Zizyphus Baclei*, dieselben gallenartig deformierend, hat also dieselbe Nährgattung und dieselbe Heimat. Es ist sogar ganz gut möglich, daß *Coniodyctium Chevalieri* H. et Pat. und *Hyalodema Evansi* P. Magn. dieselbe Art sind, sichere Unterschiede lassen sich wenigstens aus den Beschreibungen nicht entnehmen. Der von Magnus beschriebene Pilz scheint die Nährpflanze früher befallen zu haben.

[1]) Fortsetzung von Ann. mycol. 1905, III. p. 548.

Diseases of the Areca Palm[1]) (Areca catechu L.).

I. Koleroga or Rot-Disease.

By Leslie C. Coleman, M. A., Ph. D., Mycologist & Entomologist to the Government of Mysore.

(With Plates VII—IX.)

The cultivation of the Areca palm is one of the important agricultural industries in the Native State, Mysore. As is well known the nuts of this palm form the chief ingredient of betel, which is used almost universally throughout India and Malaysia for chewing. In Mysore it is in the western highlands that this palm is most extensively cultivated. In this region are to be found innumerable hills separated by narrow winding valleys and it is in these valleys that the large areca gardens are situated. They thus occur in more or less isolated tracts which frequently reach an extent of 100 acres. The total area of Areca cultivation in these western highlands reaches an extent of approximately 20000 acres, and the revenue derived by Government from this crop is about two lakhs[2]) of Rupees, while its total value exceeds forty lakhs of Rupees.

The Areca palm in this western highland region suffers from one of the worst fungous diseases to be found in India. This disease is known in Kanarese, the chief language of the State, as "Koleroga", which means simply „Rot Disease".

The disease restricts its attack to the rainy season or the season of the South West monsoon, which extends approximately from the beginning of June to the middle of September. Within this period in this western part of the State practically the whole of the year's rain falls. The annual rainfall is to say the least very heavy, varying from about 100 inches to 300 inches.

The disease "Koleroga" usually makes its first appearance towards the end of June, about two or three weeks after the beginning of the rains. It restricts itself for the most part to the nuts themselves but occasionally passes over into the tops of the palms in which case they very speedily succumb. The nuts soon after they are attacked begin to drop

[1]) It is proposed to publish a series of papers upon the diseases of the Areca Palm, the present being the first of the series. This paper will appear shortly, in more extended form and fully illustrated, as a Bulletin of the Agricultural Department, Mysore.

[2]) A lakh of Rupees is Rupees 100,000 or about 7,000 pounds sterling.

from the trees and it is this dropping of diseased nuts which signals the advent of the disease to the garden owners. Its spread is usually remarkably rapid so that within a few weeks an area of many acres may have become badly infected.

Koleroga has up to the present remained practically uninvestigated from a scientific standpoint and it is the purpose of the present paper to present the result of investigations which have extended over a period of about two years.

The scientific literature on the subject is, as indicated, very meagre. The first to note the disease appears to have been Cooke[1]). Unfortunately I have been unable to see Cooke's original paper, but the fact that he confuses this disease with the „Koleroga" of Coffee, the Leaf Rot Disease caused by *Pellicularia koleroga*, Cke., would appear to indicate that he did not really examine the disease at all but simply concluded from the identity of the popular names for the two diseases that they were caused by one and the same fungus. The veriest tyro would have not the slightest difficulty, after making a microscopic examination of the two diseases, in deciding that the causes were decidedly different.

The only other investigator to study the disease appears to have been Butler[2]). As, however, he was able to observe the disease only on a short tour in the affected district and as this tour was made in August towards the end of the monsoon his investigation was of necessity simply of a preliminary nature. He found on examination of affected leafsheaths and fruit-stalks, a *Phytophthora* which he concluded" from its position, anatomical characters and the enormous quantity of spores which it produces" to be an active parasite. He also states that "there is little doubt that this is the cause of the disease". He gives a short description of the appearance of the mycelium in the infected tissues and also of the formation of sporangia and zoospores, but no remarks with regard to the actual species under investigation. His remarks with regard to the first appearance and spread of the disease were of necessity largely based upon information furnished to him by garden owners and are therefore incomplete and in part appear to be incorrect. These, however, will be discussed later.

In their "Fungi Indiae orientalis", Sydow and Butler[3]) identify this fungus as *Phytophthora*? *omnivora* de Bary giving as habitat "in foliis, fructibus pedunculisque *Arecae katechu*, Koppa, Mysore".

From the above it may be seen that uncertainty exists as to the real position of this fungus. In this connection it may be noted that a *Phytophthora* which has, following the identification of Massee[4]), usually

[1]) Cooke, Popular Science Review No. LIX cited from von Faber, Die Krankheiten und Schädlinge des Kaffees. Centr. Bakt. Abt. II Bd. 21, S. 113, 1908.

[2]) Butler, Agricultural Journal of India, Vol. I, p. 299, 1906.

[3]) Sydow et Butler, Annales Mycolog. Vol. V p. 512, 1907.

[4]) Massee, Kew Bulletin, 1899, p. 1.

been considered as *Phytophthora omnivora* de Bary has been found on several different hosts in the tropics of Asia, Africa and America and a

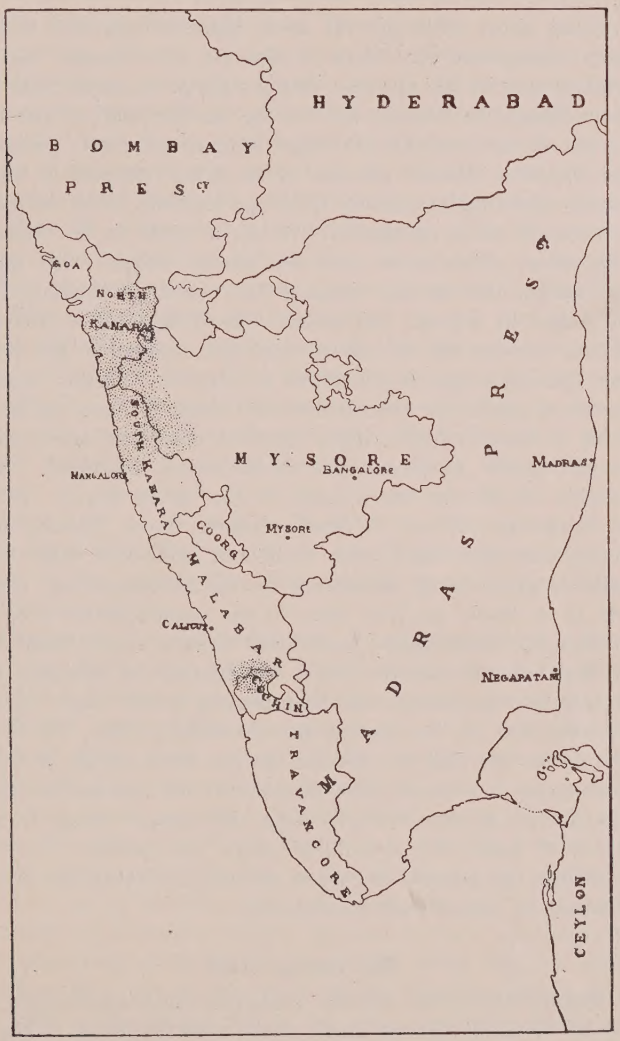

Fig. 1. Map of Southern India. The two areas marked with dots are the areas affected by Koleroga.

considerable literature has been published upon it without however settling beyond doubt that the fungus is really identical with the European fungus so carefully investigated by Hartig, de Bary and others. The chief host plant

is the Cacao and as extensive investigations were being carried out on the Areca fungus it seemed to me a favourable opportunity for a comparative study of the two fungi in order to settle, if possible their real position.

As stated above although the areca palm is cultivated more or less extensively throughout the whole of Mysore, this disease has appeared with certainty only in the extreme western parts. A single case has been noted from Bangalore district well to the eastern part of the State, but I am not yet certain that the Koleroga fungus was really present in this instance. The area affected consists of an extent situated in the Western Ghauts and extending practically from the extreme north of the State to a point about 80 miles southward. It has a width in its widest part of about 30 miles. This area coincides pretty closely with the area of heaviest rainfall, the rainfall ranging between approximately 100 inches and 300 inches in a year. As already stated by far the greater part of the rain falls between the months of June and September and it is during this time that Koleroga is prevalent in Mysore. Farther south in the Western Ghaut region the disease does not seem to have spread although the rainfall is almost equally high. Here however the areca gardens are much smaller, less numerous and more widely scattered. In regions lying outside of Mysore the disease is also to be found. It has been reported to me as present in North Canara, South Canara, in a small tract in Malabar adjoining Cochin State and in Cochin State itself. The distribution is given fairly accurately on the accompanying map (Fig. 1) A glance at it shows us that there is one main infected area including parts of Mysore, North Canara and South Canara and a small area to be found in Malabar and Cochin. From the information available it appears fairly certain that the disease has been present much longer in the larger northern area than in the smaller more southerly one. The Collector of Malabar informs me that the disease has not been known in that district more than about ten years. Information in this connection from Cochin is not available. In the northern area the disease seems to have been present for at least over a hundred years, and probably for very much longer. Within the memory of garden owners now living the area affected has increased in extent very considerably.

The disease itself.

As already stated the disease makes its first appearance about the end of June or about two or three weeks after the break of the monsoon. Butler's[1]) statement that the first symptoms of the disease appear at the time of flowering is incorrect. The main flowering season of the areca palm in the affected area in Mysore extends approximately from January to

[1]) Butler, l. c. p. 299.

March, fresh inflorescences breaking forth about every 15 days. A few belated flower stalks may appear as late as June but they are extremely rare, at least in Mysore. In the extreme southern part of the main areca growing district are to be found gardens where the main flowering season is June, but here no disease is to be found. In the many gardens visited during the month of June I saw less than half a dozen such young stalks and these showed no sign of the disease. As will be seen later the flowers and flower-stalks, especially the male ones, are quite susceptible but owing to the fact that they appear during the dry season they do not play any role in the development and spread of the disease. The disease first makes its appearance upon the partly-developed nuts which usually drop off soon after the attack and it is this dropping of the nuts which gives the garden owners their first intimation of the appearance of the disease. A bunch that has been attacked by the disease is shown in Plate VII, Fig. 1.

Such fallen nuts almost invariably show on the surface a felty mycelial mass which usually begins to make its appearance near the base of the nut and spreads from there gradually over the whole surface. (See Plate VII, Fig. 2). In favorable specimens this mycelium is seen to be a practically pure growth of a Phycomycete. Embedded in it are usually to be found numerous sporangia generally oval in shape. A study of the emission of the spores from these sporangia leaves no doubt but that we have here to do with a *Phytophthora*. The sporangia are very readily loosened from their points of attachment and so in microscopic preparations of the surface-felt they usually appear lying loose in the meshes of the mycelium.

An examination of a diseased bunch of nuts shows still earlier stages of the disease. Before any sign of mycelium appears on the surface the presence of the disease is usually indicated by a more or less extensive patch of darker green which is quite easily to be distinguished from the beautifully clear green colour of the healthy nut (See Plate VII, Fig. 3). It gives the impression of the affected area being water-soaked. Soon after this there appears a number of minute papilliform elevations which mark the points at which the fungus will break forth on to the surface. The fungus makes its exit to the surface in two different ways, by the stomata and by breaking or bursting the outer wall of epidermal cells. In the majority of cases the fungus appears to form sporangia immediately after appearing on the surface, the result being that on examination of the surface of a nut at this stage of the disease under a low power numerous tufts of sporangia are to be seen apparently sessile upon the surface of the nut. In other cases, however, and this seems to be especially the case where the fungus has broken through epidermal cells, mycelial threads of considerable length are formed before any sporangia appear. In any case hyphae soon grow out from beneath and gradually grow together to form the felt-like net-work characteristic of later stages

of the disease. It is practically impossible to make out the system of branching of the sporangiophores by observation of the fungus as it appears on the surface of the nut. When however small pieces of the nut or of the nut shell are brought into water (distilled water or rain water were usually employed) in a petri-dish the whole process can be very readily studied. It can be seen that the first sporangium on a sporangiphore is formed terminally while the next one is formed terminally on a branch which grows out usually at a short distance below the base of the first sporangium and that this gradually pushes the first aside so that it comes to lie laterally. In other words we have here the method of sporangium formation typical of the genus *Phytophthora*. This together with the method of escape of the zoospores leaves no doubt that the fungus belongs to this genus. A discussion of its nearer affinities will be given later.

A study of the course of the fungus in the interior of the nut-shell reveals the fact that in the earlier stages, and even in later stages in the deeper lying tissue, the mycelium is practically confined to the intercellular spaces of the parenchyma Haustoria are scarce but are however to be found on careful search. They consist of finger-like processes which are at times dichotomously branched. Spherical haustoria such as described by Hartig[1]) for his *Phytophthora Fagi* (*Phytophthora omnivora* de Bary) were at no time to be found. The fungus does not however entirely confine itself to the intercellular spaces. Later on, especially in the tissues of the shell lying near the surface, it is to be seen abundantly in the interior of the parenchyma and epidermal cells, so much so that the lumina seem practically filled with mycelium. Here and there in the vessels of the fibrovascular bundles which run longitudinally in the shell in great numbers was also to be found mycelium. Where the fungus breaks out through an epidermal cell to the surface it appears at least in the majority of cases to be, practically, purely a physical matter. The pressure of the mycelial mass beneath bulges out the outer wall and this finally gives way. Many preparations show such a breaking forth and in them the torn edges of the outer epidermal wall are frequently clearly visible. In such cases the fungus mycelium frequently enlarges to a more or less globular swelling immediately beneath the outer epidermal wall previous to bursting it.

The course of the mycelium in the nut itself cannot so easily be made out. In the immature condition in which the nut finds itself at this time of the year a cross section shows a series of brownish dissepiments extending towards the centre of the nut along radial lines. The tissue here is smaller celled with somewhat more distinct cell walls. Along these dissepiments the vascular bundles make their way into the centre of the nut from the netlike raphe which spreads over the outer

[1]) Hartig, Unters. aus forstbot. Inst. München, 1880 I, pp. 41 u. 42.

surface of the nut[1]) The pale tissue lying between these dissepiments is still in the process of formation and consists of larger cells with thin cell walls[2]). The mycelium seems to make its way in from the surface of the nut almost entirely along the dissepiments and from here it extends laterally into the soft tissue on each side.

As stated the disease usually confines itself to the nuts. Occasionally however the tops of the trees are also infected. Butler[3]) has also noted this infection of the tree tops. It is hard to estimate the exact percentage of trees thus killed but it is certainly very small and in my experience rarely exceeds one percent of the trees in an affected garden in any one year. As the trees in this region extend up to 70 or 80 feet in height, the disease in the top of the tree can be made out only after it is fairly well advanced and the growing point itself has become affected. It is therefore difficult to decide just where the preliminary infection takes place. There seem however to be two separate ways of infection. One of these is illustrated in Plate VIII. In this specimen the stalk of the bunch was completely dead and the parenchymatous portions almost entirely decayed leaving the fibre-bundles and fibrovascular bundles free. Examination of sections of the stem taken near the point of attachment of the bunch showed the *Phytophthora* mycelium in abundance. The hyphae were found to run here in the parenchyma chiefly intercellularly; they could however be easily traced into the fibrovascular bundles themselves where they were to be found in the interior of the parenchyma cells surrounding the vessels and proceeding from here into the vessels themselves where they pursued a fairly regular longitudinal course. In this connection it may be noted that according to Butler[4]) his *Pythium palmivorum* which attacks the tops of *Borassus flabellifer*, and to a less extent those of *Cocos nucifera* and *Areca catechu* in the Godaveri Delta, Madras Presidency, never enters the fibrovascular bundles. On the other hand *Phytophthora omnivora* de Bary has been found even to form oospores in the tracheids of coniferous seedlings. Lindau[5]) states „In den Wurzeln der Koniferenkeimlinge trifft man die Oosporen sowohl im Rindenparenchym, als auch im Innern der Tracheiden, in denen sich die Pilzfrüchte mit ihrer Gestalt dem langgestreckten Raume anpassen und länglich werden". As indicated in the figure the tissue in the neighbourhood of the growing point of the palm

[1]) It appears unnecessary to give here a detailed description of the anatomy of nut and nut-shell. Those desiring information on this point are referred to Engler und Prantl, Pflanzenfamilien, II. Teil, Abt. 3, p. 21.

[2]) Later, of course, the walls of these cells become very thick as the reserve material of the nut is deposited chiefly in them in the form of cellulose.

[3]) l. c. p. 299.

[4]) Butler, An account of the Genus Pythium etc., Memoirs of the Department of Agriculture in India, Botanical Series, Vol. I, No. 5, p. 82, 1907.

[5]) Lindau, Sorauer's Handbuch der Pflanzenkrankheiten, Bd. II, p. 151.

appears when split open to be quite healthy as do also the bases of the leaf-sheaths enclosing it. Sections taken in the neighbourhood of the growing point revealed no trace of the mycelium, which shows quite conclusively that the fungus has really entered into the stem by the diseased bunch-stalk and not through the leaf-sheaths.

The tree top pictured in pl. IX shows a decidedly different condition. Here the nuts have become diseased and have dropped off but the bunch stalk at the base appears perfectly healthy nor could any trace of mycelium be found in sections taken from it. On the other hand the growing point was badly decayed and the course of decay seemed to have been along the line of the bases of the leaf-sheaths which form the protective covering to the tender growing point of the stem. Preparations made from the decayed growing-point showed the typical *Phytophthora* mycelium in abundance together with large numbers of saprophytic organisms, chiefly bacteria. In sections of the stem taken in the neighbourhood of the point of origin of the bunch-stalk, *Phytophthora* mycelium was also found after careful search but it was very much less abundant than in the neighbourhood of the growing point and everything pointed to the probability that the disease had entered through the bases of the leaf-sheaths into the growing point and from thence had worked its way some six inches down the stem to the region of origin of the bunches.

From the above it seems fairly certain that infection of the tree-top may take place on the one hand directly from the diseased bunch by means of mycelium growing down through the stalk and thence up to the growing point and on the other hand by means of independent infection of the leaf-sheaths surrounding the growing point of the tree. Actual examination of dying tree tops shows that the first method is the more usual, but that the second method is also to be met with occasionally. Direct experiment which will be detailed later on in this paper shows conclusively that infection of the top through the leaf-sheaths by means of spores which have germinated on the outer surface can take place.

It is rather difficult to account for the rarity of attack on the tree tops as compared with that on the bunches. Direct infection by means of zoospores germinating on the surface of the external leaf-sheath must, of necessity, be rare as during the heavy showers of the monsoon the rain water directed by the leaves runs in streams down over this outer surface and so must wash away the great majority of the zoospores that may have been deposited there. This, however, does not apply to the cases where infection has taken place through the bunch-stalk and the rarity of infection even by this means must for the present remain unexplained.

Infection Experiments.

In order to establish the parasitism of the Areca-*Phytophthora* extensive infection experiments have been carried out. The first of these were

conducted in a small temporary laboratory set up in the heart of the affected area, during the rainy season of 1909. Inoculating material was obtained (a) directly from scrapings, from the surface of diseased nuts, suspended in water and (b) from pure cultures. In addition infection experiments were attempted by suspending healthy nuts in water over a small quantity of soil taken from a garden where the disease was prevalent or in other cases in water over a number of diseased nuts.

Inoculation experiment with material direct from the surface of diseased nut:

Sporangia were scraped from diseased nuts showing discrete sporangial sori and shaken up in sterilized distilled water. A total of 49 healthy nuts were washed thoroughly with distilled water and placed in dishes. They were inoculated with a loop of the watery suspension of sporangia and zoospores and the spot was marked with an inked ring. 34 nuts were placed under moist bell jars and 15 were left free to the air. At the same time the suspension was microscopically examined. The majority of the sporangia in it had already emptied themselves. Many of the zoospores were swimming about in the water while others had come to rest and had rounded themselves off. Inoculation was made on 23rd July 1909 at 5 P. M. On 24th July 1909 a microscopical control of the inoculations was made. Tangential sections were made so as to remove the epidermis in the inoculated area. Sections made at 9 A. M. and 11,30 A. M. showed numerous zoospores sprouted out on the surface but no penetration could be made out. In a number of cases the ends of the germ tubes had slightly enlarged into somewhat spherical swellings which resembled the appressoria formed by many parasitic fungi and described and figured by me for *Sclerotinia Trifoliorum*[1]). Here, however, also no penetration could be made out.

In sections made at 1 P. M. and 4 P. M. penetration was quite common and in every case the entrance had been accomplished through a stoma. In some cases a single zoospore had germinated near a stoma and had immediately sent down a penetration tube. In other cases a large number of germ tubes could be seen converging from all directions to the stoma and entering closely packed together. The zoospore was in many cases quite empty and also in a good many instances a part or the whole of the penetration tube had lost its protoplasmic contents. On the other hand could be found those zoospores and germ tubes which still contained protoplasm in apparently undiminished quantity. The very characteristic appearance shown in the sections illustrates beautifully the role that chemotropism plays in the penetration. This question of chemotropic action will be discussed in a subsequent paper. Transverse sections of the shell

[1]) Coleman, Über Sclerotinia Trifoliorum etc. Arbeiten aus d. Kaiserl. Biolog. Anst. für Land- und Forstwirtschaft, Bd. V, Heft 7, 1907, p. 478 et seq.

showed in some cases penetration tubes in the substomatal chamber but they had not yet penetrated into the parenchymatous tissue of the shell.

A large number of nuts were used for the purpose of studying the penetration so that only 11 infected nuts were left under the bell jar. A daily examination of the inoculated nuts was made and on 28th July 1909 the first signs of the fungus appeared on the surface. Of the 15 nuts left free to the air 14 showed a number of distinct sporangial bunches broken forth in or close to the area covered by the inoculating drop. Of the nuts left under moist bell jars 3 still showed no sign of the disease. The rest showed the beginning of an outbreak, especially when examined with a hand lens. In one case the nuts showed the presence of sporangial tufts quite distinctly. Two of the nuts were used for sectioning and the others were left. Three of the four nuts which on the 28th July did not show signs of disease developed it later, so that only one nut remained uninfected.

Tangential sections of nuts showing the more advanced stage of disease showed the sporangiophores coming out from the stomata as well as breaking through epidermal cells. The primary sporangiophores are as already indicated very short so that the sporangia appear almost or quite sessile on the surface of the nut. Later stages of growth to the formation of a felty mass enveloping the nut were as already described.

It is unnecessary to detail the results of further inoculation experiments. Suffice it to say that with suspensions prepared from slightly diseased nuts as with those from pure cultures in sterilized distilled water the results were much the same and there was an average of from 80—90 % of the nuts inoculated that took the infection. Penetration was found and studied in numerous cases and in every case the entrance of the germ tube took place through a stoma. Penetration was to be observed about from 12 to 18 hours after inoculation under conditions prevailing in the affected area, while under similar favorable conditions the fungus appears on the surface of the nut within 4 or 5 days after the inoculation.

In addition to infection experiments where suspensions of the zoospores were used, others were carried out where the diseased nuts were placed in a beaker and healthy nuts suspended above them in water. Here too similar results were obtained. Lastly an attempt was made to infect nuts by means of soils taken from the gardens suffering from the disease. In this connection I would recall somewhat similar experiments made by R. E. Smith[1]) with the *Pythiacystis citrophthora*, the cause of a rot of the lemons in California. Hartig's investigation on *Phytophthora Fagi* (*Phytophthora omnivora* de Bary)[2]) also showed that the oospores of this

[1]) R. E. Smith, Brown Rot of Lemon, Univ. of California Publications, Bulletin No. 190, 1907, p. 19.

[2]) Hartig, Untersuchungen aus dem forstbotanischen Inst. München I, 1880, p 33.

species were capable of remaining in the soil four years without losing their power of germination. Preliminary experiments indicate that soil or leaf mould that has been removed from an infected tree and kept in a dry place for a couple of weeks is able to infect healthy nuts if it is placed in distilled water over the soil in a beaker or other vessel. Whether this infection takes place through oospores present in the soil and just how long such soil will remain capable of infecting are subjects at present being investigated. In any case attempts to cultivate the fungus in pure cultures on sterilised leaf mould or soil taken from the garden met with very little success. Appreciable growth could be obtained only when the leaf mould or soil had been soaked with malt extract, and even in this case the growth was sparse and only a few sporangia and no oospores could be found.

Infection experiments were also made with suspensions of zoospores directly placed on the outer leaf-sheaths of an Areca top. The course of penetration was not followed microscopically, but an examination made two weeks after the inoculation showed that the fungus had grown right through the several underlying leaf-sheaths, and had attacked the growing point. Mycelium and sporangia were to be found on both the outer and the inner surfaces of the leaf-sheaths. As noted already the fungus was here found not only in the ground parenchyma but also in the fibrovascular bundles and in the vessels themselves. These experiments clearly show that a direct infection of the tree top by means of zoospores is possible.

Finally, male and female flowers and flower-stalks were inoculated with suspensions of zoospores from pure cultures of the fungus. Three different stages were taken, namely, (a) flowers a few days before the opening of the spathe, (b) flowers three or four days after the opening of the spathe and (c) flowers about 15 days after the opening of the spathe. In the case of (a) and (b) flowers and flower stalks were still quite white while in (c) the female floral envelopes were already quite green and the male flowers dropped off in handling.

The inflorescences were in each case cut up into short sections, a number of which were placed in petri dishes. Each dish was placed in a larger one containing a layer of distilled water and over it was placed a cone of moist filter paper which dipped into the water. Over this again was placed a bell-jar. It was attempted in this way to reproduce as nearly as possible the moist conditions prevailing in the affected area during the monsoon. In fact this kind of moist chamber was used for all the later infection experiments carried out at head-quarters during the dry season and was found to answer fairly well.

Four days after the inoculation the first signs of infection could be seen on some of the male flower stalks of (a). After 6 days the *Phytophthora* mycelium appeared on the surface of a section of flower stalk in plate (c)

In (a) most of the male branches were by this time infected. The infected branches had gradually changed their whitish color through gray to black.

After 8 days there was little change except for an advance of the disease on the pieces of inflorescence already infected. On plate (a) all four branches bearing male flowers were infected. Of the 5 branches bearing female flowers 3 were infected. On plate (b) no infection had taken place there being nothing to be found but a small amount of saprophytic mycelium. On plate (c) only one branch bearing female flowers had become infected, the other four had not.

Although the results were not as good as might be desired, still they show clearly that the fungus is able to infect both flowers and flowerstalks. It must not be forgotten that this experiment was carried out in February during the driest time of the year and that the fungus material used for inoculations had been growing in pure culture in the laboratory for about 7 months. It should be further noted at this time that notwithstanding every effort to reproduce the climatic conditions existing at the time the disease is prevalent, infection experiments have not been so uniformly successful in Bangalore during the dry season as were those carried out in the affected area during the monsoon.

It is hardly necessary to add in concluding this description of inoculation experiments that in all cases the material used consisted of a suspension of zoospores in water. This is without doubt the chief if not the only natural mode of infection. Further in no case was the surface of the material inoculated wounded in any way. In fact every attempt was made to reproduce natural conditions as far as that is possible in a laboratory.

Morphology of the Fungus.

The mycelium of the Areca-*Phytophthora* possesses the usual Phycomycete characters. The protoplasmic contents are marked by their granular appearance and are loaded with fat for the most part in a fine state of division. Septa are comparatively rare, appearing in the vegetative mycelium only at an advanced stage. The hyphae vary much in breadth reaching a width of 8 or 9 μ.

The sporangiophores in water cultures appear rather irregularly branched and agree well with the description given by de Bary[1]) for those of *Phytophthora omnivora*. The sporangia vary considerably in size and shape. Extreme measurements were 20,6 μ ⩽ 30,1 μ, 45,4 μ ⩽ 51,2 μ, and 43,3 μ ⩽ 71,0 μ. Fairly frequently they possess a sort of apophysis. The development of a sporangium in one case kept under continuous observation occupied a period of about 4 hours, from the time of beginning formation to the time of emission of zoospores.

[1]) de Bary, Zur Kenntnis d. Peronosporeen II, Phytophthora omnivora, Bot. Ztg., 1881, p. 587.

The formation and emission of zoospores in a sporangium is clearly influenced by external factors, chief of which is a certain strength of light. This applies not only to the Areca-*Phytophthora* but appears to be a characteristic of many Phycomycetes though I have been unable to find any reference to it in the literature at my disposal. In the case of the Areca-*Phytophthora* if a water culture containing sporangia, or a suspension of sporangia in water, be placed on the stage of a microscope and be illumunated by means of mirror and condensor almost invariably within 10 or 15 minutes, if the culture is healthy, the zoospores commence emerging from the sporangia in numbers. If cultures are kept in the dark the sporangia can be kept intact for over a month and later as soon as they are brought out to the light on the microscope stage the spores commence emerging after 10 or 15 minutes. On the other hand cultures of a few days growth will show exactly the same phenomenon. As indicated above if a sporangium be kept in the light on the stage from the time it begins to form till the time it empties it is found able to complete the whole cycle in about 4 hours at the ordinary prevailing temperature.

Whether the formation of the sporangia themselves is partially dependent upon the admission of light is not certain from the experiments performed by me. My first experiments seemed to indicate that light played no part but in this case a rather frequent microscopic control may have allowed for an amount of light getting to the cultures sufficient to bring about the formation of sporangia. In a later experiment 12 pure cultures on areca nut slices in petri dishes were prepared and kept in a dark cupboard. These cultures were prepared on 5th July 1909 and underwent a very hurried examination on 9th July 1909 to see that they were growing. They were next examined on the 14th August or about 5 weeks after they were prepared. There was a well marked growth of mycelium but no sporangia in any of the cultures. Six of the plates were placed at the window and the other six were returned to dark cup-board. On the 16th August the plates left at the window were examined. Four of them were found to contain sporangia and two none. Of the six returned to the cup-board none showed any sporangia formation. Examination later gave no change in the result as regards the cultures kept in the dark. The water of the two cultures at the window which had formed no sporangia was changed on the 21st August. On the 24th a very few sporangia were to be found on one of the two plates but the other culture remained sterile. No further change took place.

From the above experiments it seems probable that the presence of a certain strength of ligth is necessary not only for emission of the zoospores but also for the formation of sporangia. Further and more carefully carried out experiments are, however, required before a definite statement can be made. It is possible the rise of temperature associated with the increase of light may have had some influence but this seems to me hardly likely.

It is interesting in this connection to note Klebahn's observations on his *Phytophthora Syringae* which is undoubtedly closely allied to *P. omnivora*. This fungus does not appear to produce sporangia on its host plant (*Syringa vulgaris*) and Klebahn[1]) first observed their formation after growing the fungus in pure water. These sporangia did not give off zoospores and it was only after Klebahn replaced the water of the culture with fresh water which had been saturated with oxygen that he succeeded in getting any results. He describes the course he pursued as follows: — „der Wassertropfen, in dem sich die Sporangien entwickelt hatten, wird mit einem Kapillarrohr abgesogen und durch Sauerstoff-gesättigtes Wasser ersetzt. Diese Operation wird zwei bis dreimal nacheinander wiederholt und dann die Kultur in der feuchten Kammer beobachtet" — „nach ungefähr einer Viertelstunde beginnt dann das Ausschwärmen der Schwärmsporen " On the other hand Klebahn found sporangia of *P. omnivora* to empty themselves in ordinary water without any special treatment. He does not appear to have noticed any effect of light on the process at all.

Time has failed for the carrying out of exact experiments on the factors affecting the formation of sporangia and the emission of the zoospores, but it is proposed to investigate this very interesting question more fully in the near future.

This question of the influence of light on the formation of sporangia and the emission of zoospores has a decided practical interest in the case of the Areca-*Phytophthora*. The general opinion of garden owners throughout the whole infected tract in Mysore and elsewhere is that the spread of the disease is very much favored by weather conditions where rain and sun-shine alternate every few hours. Such a belief is of course the result of years of observation and I have as yet not had the opportunity to form an independent opinion on the question. If such be really the case it seems highly probable that the fact is connected with the influence of light on the emission of zoospores. Germination of the sporangia direct as conidia, has been extremely rarely seen although hundreds of cultures and preparations containing sporangia have been examined. At times a number of the spores do not succeed in escaping and these may germinate in situ sending out germ tubes through the wall of the sporangium[2]) but ordinarily all the spores escape. A rapid alternation of rain and sun-shine would favor the emission of zoospores in large numbers; the intervening showers would keep the air saturated with moisture and the rain along with the wind would allow the zoospore-laden rain-drops to be carried from one bunch and one tree to another.

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[1]) Klebahn, Krankheiten des Flieders, Berlin 1909, p. 49.

[2]) cf. Hartig loc. cit., p. 44.

[3]) von Faber, Die Krankheiten und Parasiten des Kakaobaumes. Arbeiten aus d. Kaiserl. biolog. Anst. f. Land- und Forstwirtschaft, Bd 7, Heft 2, p. 201.

The zoospores are the typical oval biciliated bodies of the genus and agree with the description given by de Bary, Hartig, von Faber[3]) and others for *Phytophthora omnivora* and the Cacao-*Phytophthora*. As Klebahn has noted for *Phytophthora Syringae* the two cilia are of unequal length, the anterior one or the one directed forward being shorter than the posterior one. The following measurements of a zoospore fixed with osmic acid give the approximate dimensions. Zoospore 11,3 μ ⩽ 8 μ. Anterior cilium 20,7 μ. Posterior cilium 29 μ.

After swimming about for a comparatively short period of time the zoospores come to rest, round themselves off and soon afterwards germinate sending out one or more germ tubes. The following experiment gives data as to the periods of swimming etc. under the normal conditions of temperature existing in the affected area.

2,20 P. M. Pure culture containing sporangia placed on stage of microscope;

2,30 P. M. Zoospores commencing to come out of sporangia;

2,45 P. M. 29 drops of water containing swimming zoospores placed on slides; all the zoospores were still swimming;

3,00 P. M. In every one of the drops some zoospores have come to rest. In some few drops all have done so. There is every gradation up to drops in which the great majority of the spores are still swimming.

3,15 P. M. In 12 of the 29 drops all the zoospores have come to rest. In others a gradation as before. No spores have begun germinating.

3,30 P. M. In practically all the drops germination has begun.

3,45 P. M. Germination general.

4.00 P. M. In 12 drops zoospores still swimming.

4.25 P. M. A very few zoospores still swimming in a few drops.

4.45 P. M. Zoospores have all come to rest, most of them are germinating.

From the above it can be seen that under conditions such as exist in the affected area (a) under favorable conditions of light emergence of zoospores begins after about 10 minutes, (b) the length of the swimming period varies from about 30 minutes to $2^1/_2$ hours and (c) germination commences or becomes visible from 20 to 30 minutes after the zoospores come to rest.

The extreme rapidity of the whole process enables us better to understand the very rapid spread of the disease once it has appeared in a garden.

Sexual Organs. Neither sexual organs nor oospores have as yet been found on diseased nuts or diseased tops from infected gardens although a long and careful search has been made for them. An attempt to cultivate the fungus from old diseased nuts which had remained in the garden for a year also failed. It seemed then that the fungus resembled *Phytophthora infestans* in lacking oospores entirely. However these organs were found later both in laboratory cultures and on other species of plants

inoculated with the fungus. In the laboratory the sexual organs were found on pure cultures growing on inoculated areca nuts which had been previously removed aseptically from their shells and placed in sterile Roux tubes over water.

It is of course premature to state that the fungus does not form sexual organs under natural conditions in the areca gardens. In fact it is highly probable that such does take place. From the careful investigation already made it appears certain however that such formation must be of comparatively rare occurrence. Considering the abundance with which they are formed in aseptic cultures on areca nuts it seems highly probable that the reason for their nonappearance or rarity under natural conditions must be sought in the influence of the saprophytic organisms which are to be found in abundance on every nut showing a stage of the disease at all advanced. It is these organisms which really produce the rot of the nut, for aseptically taken nuts inoculated with pure cultures show no signs of such rotting. The rot resulting from the attack of other *Phytophthora* species and related fungi has also been shown to be largely of secondary origin.

The saprophytic organisms most commonly to be met with are different kinds of bacteria and a species of *Tubercularia* whose pinkish, cushion-like fructifications are to be found on the surface of the shell of almost every nut in an advanced stage of disease. That the saprophytic organisms exercise a marked influence upon the growth of the *Phytophthora* is quite certain. At times in the case of artificial infections carried out under unfavorable conditions they so masked or overgrew the *Phytophthora* on the surface of the nut that the latter formed no sporangia whatever. As it is impossible to indentify this *Phytophthora* with certainty by means of the mycelium it was found necessary in such cases to remove the nut as aseptically as possible from the shell and grow it in water culture. When this was done formation of typical sporangia readily took place and the fact of infection was thereby established.

The fact that the Areca-*Phytophthora* has been successfully used in inoculating other plants suggests the possibility that the fungus has other host plants in the infected area. Unfortunately the formation of sexual organs and the infection of other plants were established only after the end of last year's monsoon so that an investigation of this side of the question could not be taken up. It will form one of the most important subjects of study during this year's monsoon. The discovery of intermediate hosts especially if it be found that the fungus regularly produces sexual organs and oospores upon them would, needless to say, be a matter of great practical importance.

Growth of sexual organs on inoculated areca nuts will be described in a future paper. Suffice it to say here that the sexual organs seem to be formed almost always on the mycelial felt on the surface of the nut and

rarely in the nut tissue itself. The formation of the oogonia and the antheridia is very similar to that of *Phytophthora omnivora* so carefully described by de Bary[1]). The antheridium and oogonium arise close together as branches of the same thread and in only one doubtful case on another host did the antheridium appear to arise from a separate thread. As to the time of formation of the two organs it appears that, in some cases at least, the antheridium begins to develop first. The antheridium arises as a terminal swelling on a thread and soon after the oogonium develops as a branch immediately beneath it. This branch grows past the antheridial branch and becomes closely applied to it, at the same time swelling out at the end. The oogonium on being rounded off thus comes to lie immediately above the antheridium which is applied to its base. The formation of oogonia and antheridia bears a striking resemblance to the formation of two sporangia on the same sporangiophore. How far this resemblance has to do with a real relationship between sexual and asexual organs must remain for the present simply a matter of conjecture.

A similar course of development is described by Clinton[2]) for the sexual organs of *Phytophthora Phaseoli*, but the earlier development of the antheridium is even more marked. He states: — "In the development of the sexual stage the antheridium is the first to appear and is often apparently fully developed before there is much evidence of the oogonium". De Bary[3]) on the other hand would appear to think that the oogonium begins to be formed slightly before the antheridium. He adds after stating the two organs begin to be formed "fast gleichzeitig"; "Ob die Anlegung des Oogons jener des Antheridiums doch um kurze Zeit vorausgeht, war bei dem gewöhnlich dichten Gewirre von Zweigen und Zweiganlagen an fructificierenden Orten nicht möglich mit Sicherheit festzustellen".

The differentiation of the oosphere and the fertilization process have been studied only in a preliminary manner and on living material. They appear to agree very closely with the careful description given by de Bary for *Phytophthora omnivora*. The cytological aspect of fertilization has as far as I am aware not as yet been investigated in any species of this genus. Work on it has been begun and a detailed study of the formation of the sexual organs and of the fertilization processes will form the subject of a second paper.

As already stated, the oospores are larger than those of *Phytophthora omnivora*. I found their diametre to vary from 23 μ to 38 μ.

2. Pure cultures of the Areca Fungus: Along with inoculation experiments it was decided to attempt its growth in pure cultures on various

[1]) de Bary, Beiträge zur Morphologie und Physiologie der Pilze, IV, 1881, p. 22.

[2]) Clinton, 31st and 32d Report of Connecticut Agr. Exper. Sta. 1907 and 1908, p. 902.

[3]) l. c. p. 23.

artificial media. As far as the literature available indicates, four species of *Phytophthora* have been grown in absolutely pure culture up to the present. *Phytophthora infestans* was obtained and studied in pure cultures first by Matruchot and Molliard[1]) and later by Clinton[2]), and *P. Phaseoli* has been isolated and grown in pure culture by Clinton[3]). In addition Klebahn[4]) in his paper on *P. Syringae* published lately, gives an account of pure cultures of both *P. Syringae* and *P. omnivora* obtained by him. The statement made by Matruchot and Molliard and also cited by Clinton that van Breda de Haan[5]) had isolated and grown in pure culture his *Phytophthora Nicotianae* seems to rest on a misapprehension. I have read van Breda de Haan's paper carefully and can find in no part of it a statement that he had obtained a pure culture.

It appears to be very difficult if not impossible to isolate the Phytophthoras by the ordinary plate method on agar or gelatine. On account of their comparatively slow growth they are almost certain to be overgrown by other organisms, either fungi or bacteria. It is necessary therefore to attempt some other method. Matruchot and Molliard in their investigation of *Phytophthora infestans* used as substratum living pieces of potato tuber taken aseptically and placed in a sterilized tube.

These tubes they inoculated with conidia from a piece of *Phytophthora*-infected potato kept for a couple of days in a moist chamber. With care they were able by this means to get a number of pure cultures. Clinton notes the practical impossibility of accomplishing the isolation of *Phytophthora infestans* by means of Petri dish cultures and also indicates that the method adopted by Matruchot and Molliard is unsatisfactory. He attempted two methods of isolation both of which proved successful; one was to cut out aseptically from slightly diseased tubers pieces of diseased tissue and to insert these in sterilised tubes on the nutritive medium and the other was to hang infected leaves over aseptically taken pieces of potato tuber so as to allow the conidia to drop on to the tuber. Clinton isolated *Phytophthora Phaseoli* (from *Phaseolus lunatus*) also by the aseptic method which he describes as follows:

"The best method for securing pure cultures is to transfer into the culture-tubes pieces of the tissue, or better whole seeds, which contain

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[1]) Matruchot et Molliard, Sur la culture pure de Phytophthora infestans de B. agent de la maladie de la pomme de terre, Bull de la Soc. myc. t. XVI, p. 209; also Sur la Phytophthora infestans, Ann. Myc. Vol. I 1903, p. 540.

[2]) Clinton, Downy mildew or Blight, Phytophthora infestans (Mont.) de Bary, of Potatoes II, 29th Report of the Conn. Experiment Station, 1905, p. 314.

[3]) Clinton, Downy mildew or Blight, Phytophthora Phaseoli, Thaxt, of Lima Beans, same report, p. 378.

[4]) Klebahn, Krankheiten des Flieders, Berlin 1909.

[5]) van Breda de Haan, De Bibitziekte in de Deli-tabak, Med. uit s'Lands Plantentuin, 1896.

mycelium of the fungus, taking these from the interior of pods showing the freshest and least contaminated external growth of the mildew." Further, "Other fungi, especially *Fusarium*, closely follow the development of the mildew and unless seeds or tissues in a very early stage of infection are selected some mycelium of these or bacteria will also be included and eventually spoil the cultures".

In the attempt to isolate the Areca *Phytophthora* the efforts to separate it on agar plates had soon to be abandoned as impracticable. The method found by Clinton to be most useful was on the other hand found to answer exceptionally well. Nuts showing an early stage of infection with very little growth of *Phytophthora* on the surface were sterilised on the surface by dipping in 80 per cent alcohol and igniting. The shell was removed by a flamed knife and then the nut either whole or in pieces was inserted into a sterilised Roux tube with water in the bottom. By this method about 50 per cent of pure cultures could be obtained. A fairly copious growth of mycelium appeared on the surface within two or three days and from this transfers were made on to various different media. Where material for infection experiments was required nuts which on growth were found to contain pure cultures of the *Phytophthora* were removed aseptically to a sterilised petri-dish and cut with a flamed knife into small pieces. These pieces were distributed in sterile petri-dishes containing sterilised distilled water or rain water and within a few days a copious growth of mycelium and sporangia could be obtained. Aseptic transfers of slices of slightly infected nuts direct to water in petri dishes also yielded a goodly number of pure cultures which gave abundant sporangia and zoospores for inoculation purposes. Occasionally the petri dish cultures became contaminated but as this was almost invariably by either a *Cephalosporium*, a *Fusarium*, or a *Penicillium* there was no danger of confusion nor could there be any doubts as to results of infection experiments, when such material was used.

Growth of the Fungus on Artificial Media.: As soon as pure cultures were obtained cultivation was attempted on various sterilised media. The following media were tried: Malt extract, Malt agar, Bouillon agar, Potato agar, Potato cylinders, Boiled rice; and the following notes indicate the nature of the growth on each.

Malt Extract. Growth at first chiefly submerged, but later after about a week good growth was found on the surface with formation of surface film. This became quite thick and tough and was found to be made up of a very densely woven mass of mycelium. Neither sporangia nor sexual organs were formed. (This even after three months).

Malt Agar in Slant Tubes. The growth was moderately good but mostly in the substance of the medium raising itself very little above the surface. On the surface the mycelium branches and rebranches in a

most complicated coral-like fashion forming structures bearing considerable resemblance to the simpler types of organs of attachment (Haftorganen) found in cultures of *Botrytis*, *Sclerotinia* etc.

Here also no trace of reproductive organs could be found. If however small pieces of agar containing mycelium were brought into distilled water a growth with formation of sporangia took place. In some of the later cultures a very few sporangia were found in more or less contaminated malt agar cultures but this was rare and the sporangium formation was very sparse.

Bouillon Agar. Growth nil.

Potato Agar. Growth similar to that on malt agar but not so copious.

Potato Cylinders. Very abundant growth of mycelium which covered practically the whole of the cylinder. Examination at the end of about three months showed the hyphae mostly empty but no sign of sporangia or sexual organs either in the tissue of the tuber or on the surface. The potato gave off a fairly strong smell of ammonia and showed a marked ammonia reaction with Nessler's reagent. The potato had not rotted nor did the starch grains appear to have been at all attacked although the tuber was crowded with mycelium.

Boiled Rice. Growth was also quite copious on this medium but here again no sign of reproductive organs was to be made out.

In addition to the above, cultures were made on sterilised flies in distilled water[1]). These in a petri dish gave quite an abundant growth of mycelium and a particularly luxuriant formation of sporangia. In fact this was found to be one of the very best methods of obtaining pure material for infection experiments.

Experiments were also made on the growth of the fungus on sterilised soil and leaf mould taken from gardens in the infected area. On neither did the fungus grow to any appreciable extent and it was only after the addition of malt extract that the fungus obtained a growth that was noticeable to the naked eye. An examination of such cultures about three months after their inoculation showed mycelium and a few scattered sporangia which appeared to be dead as their contents were pale and vacuolated and as none of them could be made to give off zoospores or to germinate at all.

The Relationships of the Areca-*Phytophthora* and the Cacao-*Phytophthora;* — It has already been remarked that the specific position of the Areca-*Phytophthora* is not at all established. The same also applies to the Cacao-*Phytophthora* which following Massee is usually considered as *Phytophthora omnivora*. Massee's description and figures are quite inadequate

[1]) Cf. de Bary, Bot. Ztg., 1881.

to allow for a decision in the matter. As Wilson[1]) has pointed out both description and figures might apply equally well to another species. He notes that the conidia as figured by Massee are somewhat more elongate than is usual in *Phytophthora omnivora* and adds, "This taken with the habitat suggests that the pod-rot of Cacao may be caused by a distinct but closely related species". Busse[2]), Petch[3]) and von Faber[4]) have also expressed doubts as to the correctness of Massee's classification. Petch states "The pod disease of Ceylon appears to be due to *Phytophthora* but whether *Phytophthora omnivora* de Bary, is doubtful as the germination of the conidia has not been observed". Von Faber remarks, in the same connection, "Seiner (d. h. Massee's) Annahme aber, daß der Erreger mit *Phytophthora omnivora* de Bary identisch ist, fehlt die Begründung", and further "Solange nicht exakt ausgeführte Infektionsversuche die Übertragbarkeit des Pilzes auf andere Pflanzen bewiesen haben, müssen wir die Artfrage unentschieden lassen"[5]). As to the morphological characters distinguishing the Cacao *Phytophthora* from *Phytophthora omnivora* von Faber notes the following:

1. While de Bary found frequently a rich branching of the sporangiophores of *Phytophthora omnivora* when they were submerged under water, von Faber could not find any such rich branching in the case of the Cacao *Phytophthora*. Rarely were more than one or two lateral branches formed.

2. De Bary found frequently 30 to 50 zoospores escaping from a single sporangium while von Faber could never find more than twenty.

3. The oospores of the Cacao *Phytophthora* are according to von Faber considerably larger than those given of *Phytophthora omnivora*. De Bary found an average diameter of 24—30 for oogonia while von Faber observed oospores with a diameter of 45 μ.

Through the courtesy of Mr. T. Petch, Government Mycologist of Ceylon, I was furnished with excellent fresh material of the Cacao *Phytophthora* which was very suitable for study and which moreover permitted a ready isolation of the fungus by the aseptic removal of slightly diseased portions of the pod and the beans.

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[1]) Wilson, Studies in N. A. Peronosporales, II, Bull. Torrey Bot. Club XXXIV, 1907, p. 387—416.

[2]) Busse, Reisebericht der Pflanzen-Pathologischen Expedition des Kolonialwirtschaftlichen Komitees nach West-Afrika, Der Tropenpflanzer, 1905 No. 1.

[3]) Petch, Ceylon Administration Reports, 1906, Part IV, Report of the Government Mycologist, p. C 5.

[4]) Von Faber, Die Krankheiten und Parasiten des Kakaobaumes, Arb. a. d. Kaiserl. Biolog. Anstalt Bd. 7, p. 199.

[5]) It should be noted here that Petch in the above cited report states that the Cacao Phytophthora attacks also the fruits of Hevea brasiliensis and Artocarpus incisa L.

As von Faber has but lately published a rather full description of the morphological characters it is necessary only to note the respects in which my examination gave different results.

As to the growth of sporangiophores under water in my early cultures I obtained results similar to those noted by von Faber. In comparison with the Areca-*Phytophthora* the sporangiophores were small and with few sporangia. Later, however, cultures were obtained where the sporangiophores were quite as complicated as those described for *Phytophthora omnivora* by de Bary. The results of the examination of hundreds of cultures of these two *Phytophthora*-forms show that the complexity of the sporangiophores and even the size of the sporangia are very variable indeed and must be used only with the greatest caution in dividing one form from another. The measurements of oospores showed a decidedly larger size as an average than that given for *Phytophthora omnivora* although I found none that measured 45 μ. The average of 30 measurements of oospores found in Cacao tissue and in artificial cultures gives a diameter of 33,3 μ, the extremes were 41,2 μ and 22,4 μ. Another feature touched upon by von Faber seems much more important than the size of the oospores, that is, the question of the absence of antheridia. Von Faber states "Oogonien und Antheridien konnte ich nicht wahrnehmen". A large number of preparations containing oogonia and oospores both of Cacao-pod tissue as well as mycelium from artificial cultures and other hostplants were examined by me and in no case could any trace of antheridia be found. In a large number of cases the original stalk of the oogonium could be seen but there was no evidence of any antheridium attached thereto. In some examples it appeared from the mode of attachment of the oogonium-stalk as if the oogonial wall had become directly the wall of the oospore by a process of thickening. This, however, was probably not the case as even where the oogonial wall could be made out it was so closely applied to the wall of the oospore that it was found only after careful examination and this leads me to think that in every case a separate oospore wall is formed. The close approximation of oogonial and oosporial walls may account for the failure of von Faber to make out the former. Massee's[1]) two figures of oospores also show no indication of an antheridium although in one the oogonial wall and stalk are figured quite clearly. As far as I am aware there is no record of the finding of antheridia in the Cacao *Phytophthora* and all the evidence at hand goes to indicate that the oospores at least in the majority of cases develop parthenogenetically. In this respect the Cacao *Phytophthora* contrasts strongly with the form on Areca where antheridia seem to be universally present and where the remains of them could be found attached to the oogonial wall long after the oospores had been fully formed and were quite mature.

[1]) l. c.

Cultures on Artificial Media; — to serve as a further comparison with the Areca *Phytophthora* a number of transfers to artificial media were made. The results were as follows; —.

Malt Agar. The growth on this medium was much like that already described for the Areca *Phytophthora*. While however the mycelium of that fungus remained quite sterile or at most developed a few sporangia here there was a very marked development of oogonia and oospores. The oospore almost invariably filled the oogonium quite full. No trace of antheridia could be found. In addition to oospores there was a sparse formation of sporangia.

Bouillon Agar. Scanty mycelial growth occurred but without formation of oogonia or sporangia.

Potato Agar. Growth much as on Malt Agar, but not so copious.

Potato Cylinders. Copious mycelial growth as in the case of the Areca *Phytophthora*. Here again oospoores were to be found in abundance, and without any trace of antheridia.

Aseptically taken Areca nuts in Roux tubes. Cultures examined about three months after inoculation from a pure culture showed a fairly copious mycelial growth on the surface of the nut. Embedded in this mycelium were a few sporangia and fairly numerous oospores. Here again although a large number of oospores were carefully examined in no case could any trace of an antheridium be found.

The following are measurements of oospores from Cacao pod, Areca nut culture, and Malt agar culture.

Oospores from Cacao pod. Average of 10 measurements, 32,0 μ. The largest measured was 38,0 μ; the smallest 22,4.

Oospores from Areca nut culture. Average of 10 measurements, 33,5 μ. The largest measured was 42,2 μ; the smallest 23,8 μ.

Oospores from Malt agar. Average of 10 measurements, 34,5 μ. The largest measured 40,0 μ and the smallest 28,0 μ.

As will be seen the measurements decidedly exceed those given by de Bary for *Phytophthora omnivora* but do not reach those of von Faber. De Bary's measurements are given for oogonia and not for oospores. He states, "Die Oospore erfüllt zur Reifezeit den blasigen Teil des Oogoniums durchschnittlich etwa zu zwei Dritteln bis vier Fünfteln. Im Vergleich zu Peronospora-Arten sind die beschriebenen Organe klein, den Querdurchmesser des kugeligen oberen Teils reifer Oogonien fand ich durchschnittlich 24 μ—30 μ groß, oft auch kleiner als 24 μ". Taking the oospores as $^4/_5$ the diameter of oogonia we would get a measurement of 19 μ—24 μ for the oospores.

On the other hand comparing the oospores of the Cacao *Phytophthora* with those of the Areca *Phytophthora* we get practically the same measurements though the oogonia of the latter appear to be slightly larger.

From a study of the morphlogical characters of the two fungi we should come to the conclusion that we have here to do with forms closely allied to *Phytophthora omnivora* but yet distinct from it. The absence of the antheridia in the case of the Cacao *Phytophthora* speaks particularly strongly in this direction.

Cross-Inoculation Experiments.

In order to gain a further knowledge of the affinity of the two fungi a number of inoculation experiments on other plants were carried out. As is well known *Phytophthora omnivora* has been found capable of infecting a very large number of plants. The following is I believe a fairly complete list.

Host	Author etc.
Cereus giganteus Melocactus nigrotomentosus	Lebert and Cohn[1]).
Seedlings of Fagus, Picea etc.	Hartig[2]).
Sempervivum species, e. g. S. albidum, S. tectorum, S. glaucum and S. stenopetalum	Schenk[3]).
Cleome violacea Alonsoa caulialata Schizanthus pinnatus Gilia capitata Fagopyrum marginatum F. tartaricum Clarkia elegans Epilobium roseum Cereus speciosissimus C. peruvianus Seedlings of Lepidium sativum, Oenothera biennis and Salpiglossis sinuata	de Bary[4]).
Calceolaria rugosa and fruits of Pirus malus and Pirus communis	Osterwalder[5]) Marchal[6]).
Seedlings of Myristica fragrans	Zimmermann[7]).
Aralia quinquefoliata var. ginseng	Hori[8]).

1) Lebert & Cohn, Cohn's Beiträge zur Biolog. I, 1870, p. 51.

2) Hartig, l. c. 1880, and Lehrbuch d. Baumkrankheiten.

3) Schenck, Sitzungsberichte d. naturforsch. Ges. Leipzig, 1875. p. 70, also Bot. Ztg. 1875, p. 691.

4) de Bary, l. c. 1881.

5) Osterwalder, Centralblatt f. Bakt. II, Bd. 15, 1906, p. 435 and Bd. 25, 1910, p. 265.

6) Marchal, Bull. Soc. Roy. de Belgique 45, 1908, p. 343 cited from Centralblatt f. Bakt. II, Bd. 24, 1909, p. 563.

7) Zimmermann, Centralblatt f. Bakt. II, Bd. 7, 1907, p. 141.

8) Hori. Bull. Jap. Agr. Dept. Bd. I, 1907, p. 153 cited from Jahresb. über Pflanzenkrankheiten, Bd. 10, 1909, p. 144

The conclusions of Hori and Zimmermann that the forms they investigated really belonged to *P. omnivora* seem to be based simply on morphological similarities. I have not however had access to Hori's original paper, so may be mistaken with regard to him.

As many as possible of these and closely related species were obtained and experimented upon, viz. *Cereus formosus*, *Clarkia elegans*, *Schizanthus wisetonensis*, *Oenothera biennis*, *Salpiglossis variabilis*. In addition to the above infection was attempted on *Solanum melongena*, *Lycopersicum esculentum* and *Solanum tuberosum*. In this connection it may be noted that de Bary's infection experiments on *Solanum tuberosum* and *Lycopersicum esculentum* were entirely without results. He states[1]) „Völlig resultatlos blieben dagegen zahlreiche Versuche der Infektion von *Solanum tuberosum* sowohl junger Blätter und Laubstengel, als junger Knollen, und von Keimpflanzen des *Lycopersicum esculentum*, also der Hauptwirtspezies der naheverwandten *Phytophthora infestans*".

In the case of all the species experimented upon successful infection was accomplished with both fungi with the exception of *Solanum tuberosum*. It seems probable that seedlings of this plant also would be susceptible but they were not available. In the case of *Solanum melongena* and *Lycopersicum esculentum* only seedlings proved susceptible. Inoculations of plants above 6 inches high were unsuccessful.

Infection experiments were invariably carried out with suspensions of freshly escaped zoospores in distilled water and taken from pure cultures. To maintain the necessary degree of moisture inoculated plants, seedlings and cuttings *(Cereus)* were kept under bell-jars constantly moist. In most cases checks, i. e. uninoculated plants were placed under exactly similarly conditions as regards moisture.

Inoculation experiments with the Areca *Phytophthora*.

1. *Cereus formosus* cuttings were inoculated with suspensions of zoospores as indicated above. Within two or three days a browning of the tissues spreading from the points of inoculation could be made out. This browning gradually passed over into a rot which spread practically through the whole of the inner tissue leaving but a thin skin still firm on the outside. A mycelial web was to be found on the surface which was made up of *Phytophthora* hyphae. Sporangia were fairly numerous and, along with those formed terminally, were a considerable number of intercalary origin. These were more or less spherical in outline resembling oogonia. In more advanced stages a lateral protuberance could be made out, and this on continued observation was seen to grow out slowly into a beak with a hyaline space in it. Through the breaking of the wall at this point the zoospores were liberated.

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[1]) l. c. Bot. Ztg. 1881.

These intercalary sporangia were found only in this case and in one lot of young Areca nuts inoculated with a pure culture of the *Phytophthora*.

Embedded in the tissue and especially in the cells of the epidermis and the layers of parenchyma immediately underlying it were to be found the oogonia and antheridia in considerable numbers. In fact it was in this inoculated material that sexual organs were first discovered.

Clarkia elegans
Oenothera biennis
Salpiglossis variabilis
Schizanthus wisetonensis

Seedlings of these plants all show about the same symptoms on inoculation. The most sensitive seemed to be the *Schizanthus* which within 2 days showed most of the leaves discolored and wilted. After 3 days all the inoculated plants were badly wilted. Mycelium could be found in abundance in the tissues of leaves and stems. Sporangia were formed on the surface and in the case of *Clarkia elegans* oogonia and oospores were to be found chiefly in the leaf tissues.

Solanum melongena
Lycopersicum esculentum

Very young seedlings between one and two inches high and possessing two to four leaves were inoculated as described above. Within four days the plants showed distinct signs of the disease and thereafter gradually wilted down. Examination of the plant showed the typical *Phytophthora* mycelium in the tissues of leaf and stem and sporangia were to be found on the surface. No oospores were found.

As stated above larger plants (4—6 inches high) did not show any evidence of disease on inoculation and the same was the case with plants of *Solanum tuberosum* of about the same size. The results here obtained are in striking contrast to those of de Bary who states, as quoted above, that all his numerous infection experiments with seedlings of *Lycopersicum esculentum* were without result. There seems however to be some uncertainty as to whether de Bary's statement with regard to the immunity of seedlings of *Lycopersicum esculentum* is to be accepted as holding universally. Bancroft[1]) in discussing the Cacao *Phytophthora* states: „*Phytophthora omnivora* has also been reported to cause a disease of cultivated tomatoes in England". He does not state his authority and the only reference to this that has come to my attention has been kindly furnished by Dr. E. J. Butler, Imperial mycologist. In a short note by Bancroft on the Brown Rot of the Tomato appearing in the Journal of the Board of Agriculture March, 1910, p. 1012 he notes the presence in the dark colored seeds of tomato fruits suffering from the above disease both in the tissues of endosperm embryo fungal hyphae "which from their characters appear to be hyphae of *Phytophthora omnivora*".

[1]) Bancroft, West Indian Bulletin, Vol. X No. 3, 1910 p. 236.

Infection experiments with the Cacao *Phytophthora* on the same plants (with the exception of the larger plants of Potato, Tomato and *Solanum melongena*) were made at the same time as the above and the results were practically identical with those already described.

The net results of these infection experiments are, that at least a number of the plants that are susceptible to infection by *Phytophthora omnivora* may also be infected by the two forms under study. In addition one plant at least which according to de Bary is not susceptible to *P. omnivora* has shown itself quite susceptible to attack by our two fungi. The results of my inoculation experiments possess a decided similarity to those noted by Klebahn in his paper cited above. As was the case with Klebahn, I was almost prepared to consider the two fungi under study as identical with *P. omnivora* after the inoculation results above recorded. He was led, and I think quite properly, to consider his fungus as a distinct species on the grounds of morphological and biological differences which persisted even when the two fungi *(P. omnivora* and *P. Syringae)* were cultivated on the same medium or had infected the same host plant. The chief morphological difference he notes is in the structure of the sporangium. The papilla found at the apex of the sporangium in all other Phytophthoras so far described is lacking in *P. Syringae.* I have unfortunately been unable to compare the two fungi under discussion in this paper with material of *P. omnivora*, which Klebahn was able to do. The account given by Klebahn of growth of *Phytophthora omnivora* on artificial media (agar, *Daucus carota*, potatoes etc.) shows some differences in cultural characters as compared with the Areca *Phytophthora*, chief of which is the formation of oospores, which I have never observed although a great many such cultures have been examined.

In addition to this, differences in the morphology, especially in the size of the oospores and in the case of the Cacao *Phytophthora* in the apparent suppression of the antheridia, would seem to justify us in distinguishing these forms if not as distinct species, at least as distinct varieties.

As to the inter-relationships of the two forms cross inoculation experiments have been carried out to attempt to settle the question whether we have really to do with one and the same fungus. These experiments have not been quite conclusive owing largely to the fact that they had to be conducted at a time of the year when conditions were not particularly favorable. Three small Cacao beans kindly furnished by Mr. H. E. Houghton Superintendent of the Madras Botanical Gardens were inoculated with zoospore suspensions from pure cultures of the Areca *Phytophthora.* Of these one remained quite unaffected, one, the smallest, showed the signs of typical brown rot and on microscopic examination revealed *Phytophthora* mycelium in the tissues but no sporangia

on the surface and no formation of oospores. The third became also decayed but apparently as a result of some slight injury and saprophytic attack, as a microscopic examination revealed no sign of *Phytophthora* either on the surface or in the tissues.

On the other hand inoculations of Areca nuts from pure cultures of the Cacao *Phytophthora* were even less successful. Altogether some 100 nuts were inoculated at various times and invariably with negative results with the exception of one single dish of six nuts about one month old which showed an unmistakable infection. Check inoculations with the Areca *Phytophthora* carried out at the same time invariably gave an amount of infection which varied considerably but was always quite convincing. It is proposed during this year's monsoon to repeat these cross inoculations with fresh material of both fungi.

In a discussion of the relationships of these two fungi with each other and with *P. omnivora* there are several points to be noted, and it will be well to consider the two forms separately.

The Areca *Phytophthora* has undoubtedly a very strong resemblance to the European form. The sporangiophores appear to be identical with those of *P. omnivora* in their mode of development and their degree of complexity in water cultures. The sporangia which vary greatly in size and shape in both forms fall within about the same limits in each. The one difference worthy of notice is the occasional formation of intercalary sporangia in the Areca *Phytophthora* as already described. The mode of attack seems to be identical in the two forms, any slight difference which may occur, such as penetration through stomata in the one case and through or between epidermal cells in the other being attributable to differences in the hosts rather than in the fungi themselves. The structure of the haustoria would at first seem to yield a point of difference. Hartig describes and figures them for *Phytophthora omnivora* as spherical while de Bary gives no definite information about them simply stating that they occur but rarely. Klebahn, however, in his recent paper, describes and figures them as rather elongate and fingerlike in which case they agree closely with those of the Areca *Phytophthora*. The only important morphological point of difference appears to be the size of the oospores. According to the measurements given by de Bary the oospores of *Phytophthora omnivora* are markedly smaller than those of the Areca *Phytophthora*. Klebahn gives no measurements for the *omnivora* material examined by him so we must presume that in this respect his results agreed with those obtained by de Bary. According to my measurements, the diameter of oospores of the Areca *Phytophthora* varies between 23 μ and 36 μ.

As to the behaviour of the two fungi in artificial media there seem to be some points of difference. Klebahn found that *Phytophthora omnivora* formed both sporangia and oospores on plum agar and apparently also on sterilised carrots (*Daucus carota*) and potatoes. In none of my cultures

of the Areca fungus on malt agar and on potatoes did I find any trace of sexual organs and a sparse formation of sporangia was observed in but one culture and that on malt agar. In all my other cultures, numbering some 20 or 30, the fungus remained quite sterile. On sterilised flies in water sporangia were formed in abundance but there were no traces of sexual organs, while on aseptically taken areca nuts sexual organs were found in numbers while sporangia were very rare. This last was clearly due at least in part to the lack of water, for on areca nut slices immersed in water only sporangia and no sexual organs were found.

The Areca fungus has been found capable of infecting a number of plants susceptible to attack by *Phytophthora omnivora*, and at least one species *(Lycopersicum esculentum)* which according to de Bary, is quite immune. The statement made by Bancroft requires scientific corroboration before we are justified in questioning de Bary's conclusions in this matter.

In this connection it is worthy of note that Klebahn, following on the positive results obtained by him with *P. Syringae* in inoculations on host plants of *P. omnivora* notably on seedlings of *Fagus*, has suggested the possibility that under *P. omnivora* we have really to do with a number of different fungi. As is well known de Bary brought under this name *Phytophthora (Peronospora) cactorum* Lebert and Cohn, *P. Sempervivi* Schenk, and *P. Fagi* Hartig. Klebahn rightly points out that the descriptions given by the different authors show a by no means complete identity of structure on the different host plants. Cross inoculations of a form found on one host plant on to the host plant of another form did not invariably give results identical with those produced by the fungus actually found in nature on this second host.

The following may serve as examples of this discrepancy: de Bary[1]) attempted infection of Cacti *(Cereus speciosissimus* and *Cereus peruvianus)* with the fungus found by him on *Cleome violacea*, *Schizanthus pinnatus* etc., but got by no means the same severity of attack as Lebert and Cohn did with *P. cactorum* on *Cereus giganteus* and *Melocactus nigrotomentosus*. He succeeded in producing only a very slight infection with the formation of a few sporangia and no sexual organs. The diseased areas were soon cut off from the healthy tissue by cork-formation. He considered the difference in results to be due to differences in the host plants as the morphological characters of the two fungi appeared to be identical. Osterwalder[2]) in his investigation of a *Phytophthora* rot of apples carried out cross inoculations on beech-seedlings and on plants of *Sempervivum tectorum*. Inoculations were made in artificial wounds on the cotyledons and leaves. They were however only partially successful. In neither case were the

[1]) l. c. Bot. Ztg. 1881.

[2]) l. c.

plants killed and from the account given the disease does not seem to have spread from the inoculated leaves. Both sporangia and oospores were, however, formed in the infected organs. From these results as well as from the morphological resemblance Osterwalder concluded that his fungus was identical with *Phytophthora omnivora*. His method of inoculation seems to me to be open to question and one would hardly need to premise a strong parasitism on the part of the fungus to account for the results obtained by him.

From the above considerations it would appear that a careful revision of the species *Phytophthora omnivora* is needed and this seems particularly necessary for those fungi found outside of Europe which have been identified as this species. It would appear, also, that other *Phytophthora* species are in need of revision. As an example, Jensen[1]) suggests the possibility that *Phytophthora Nicotianae* Breda de Haan may be identical with *Phytophthora infestans*. Somewhat similar doubts have been expressed by Clinton[2]) with regard to *Phytophthora Thalictri*.

Finally, in considering the relationships of the Areca fungus it must not be forgotten that as far as at present known it occurs in India only as a parasite of the Areca Palm and that in a rather inaccessible part of the country where the likelihood of its having been introduced from Europe seems very slight indeed. Moreover in the more northerly affected tract it appears to have been present for a very long time, probably for hundreds of years. There is, in fact, a legend among the garden owners that the disease caused by it was sent as a curse by Rama, one of the great figures of Hindu mythology.

Whether we should consider this fungus as a distinct and new species seems, on the whole, rather doubtful. Although there are some grounds for doing so I should prefer for the present to place it with *Phytophthora omnivora* but as a distinct variety until such time as I shall have been able to make a thorough search for alternate host plants and until the different *omnivora* forms have been carefully investigated. It seems advisable to name and describe the Areca fungus provisionally as follows.

Phytophthora omnivora var. **Arecae.** Differs from the type in having larger oospores 23 µ—36 µ. Sporangia usually as in *Phytophthora omnivora* but occasionally formed intercalarly. Oospores not formed in artificial cultures on malt agar and potato, rarely if at all in nature on the host plant. Mycelium inter- and intracellular, septate only in older stages. Haustoria sparse, finger-like, occasionally dichotomously branched. Habitat in bases of leaves, fruits, peduncles and apex of *Areca catechu*. Distribution — Western Mysore, North Canara, South Canara, Southern Malabar and Cochin.

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[1]) Jensen, Jaarboek van het Departement van Landbouw in Nederlandsch Indie, 1906, P. 367.

[2]) Clinton, l. c., 1907—08, P. 895.

If we now come to the second fungus under investigation, that found upon fruits of Cacao, we find greater morphological differences. It is true that some of the distinguishing characters noted by von Faber[1]) do not hold. The sporangiophores produced in water cultures are variable but may under favorable conditions reach a complexity quite as great as that described by de Bary for *P. omnivora*. The sporangia are variable in size but agree in this respect with *P. omnivora*. I have not counted the zoospores emitted by a single sporangium in this fungus but counts made on the Areca *Phytophthora* gave a number varying from 10 to over 40 which agrees with de Bary's description of *P. omnivora*. As the sporangia and the zoospores of the Areca and Cacao fungi are practically identical in size there is no reason to suppose that counts made on the latter fungus would not give similar results. Von Faber himself admits that in his cultures a normal development and emission of zoospores may not have taken place.

The mycelium and the asexual reproductive organs of the Cacao fungus resemble those of *P. omnivora* strongly. The sexual organs and products are, on the other hand, decidedly different. Not only are the oogonia and oospores decidedly larger than those of *P. omnivora* but there is also a well-marked parthenogenesis which in my experience persists in all artificial cultures and also on those alternate host plants upon which sexual organs are formed. The oospore instead of filling the oogonium two thirds to four fifths as described by de Bary, occupies practically the whole of the oogonial cavity so that it is usually difficult to distinguish the oogonial wall surrounding the oospore. Antheridia appear to be entirely absent and are certainly not usually formed. I have not seen any sign of them in any of the many preparations and cultures examined. Oogonia and oospores are formed in the artificial cultures (on malt agar and sterilised potato) in which the fungus thrives. This appears to be also the case with *Phytophthora omnivora* but, as noted, is not the case with the Areca fungus. Finally, the fungus is capable of infecting a number of the host plants of *Phytophthora omnivora* and also seedlings of *Lycopersicum esculentum*. Infection of areca nuts is produced with difficulty. From the above it appears clear that this fungus although closely allied to *Phytophthora omnivora* and the Areca fungus is still a distinct species and I propose for it the name *Phytophthora Theobromae* as indicating its typical host plant.

Phytophthora Theobromae sp. nov. Mycelium richly branched both inter- and intracellular, unseptate in the earlier stages of growth, but later forming septa which frequently serve to separate off empty and dead portions of the mycelium. Haustoria not observed, sporangia generally ovate but somewhat variable in shape. Extreme measurements as given

[1]) l. c.

by von Faber are 25 μ ⩽ 30 μ and 42 μ ⩽ 80 μ. Sporangiophores in water cultures sympodially branched as in *Phytophthora omnivora* and bearing under favorable circumstances up to 20 sporangia or more. Oogonia formed intra-matrically in the host plant as well as in artificial cultures on agar and sterilised potato. Antheridia absent or if at all present only rarely formed. Oospores entirely or for the most part formed parthenogenetically occupying practically completely the oogonial cavity, in artificial cultures spherical, in the host tissue spherical, elongate or irregular 22 μ to 45 μ in diameter. Found as a parasite on fruits of *Theobroma cacao* and also upon fruits of *Hevea brasiliensis* and

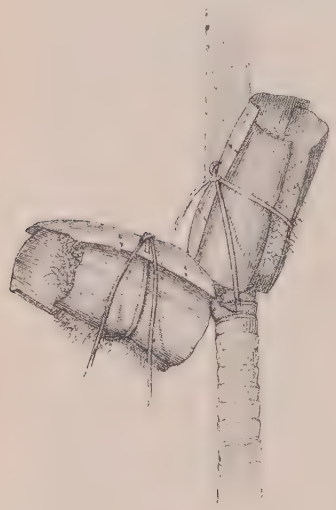

Fig. 2.

Fig. 3.

Artocarpus incisa according to Petch. Found capable of infecting a number of the host plants of *Phytophthora omnivora* and in addition seedlings of *Lycopersicum esculentum.*

Combative measures in connection with the Areca *Phytophthora:*

This side of the subject has a special interest from the fact that the owners of areca gardens have themselves devised a means of protection against the disease. Probably from the view of the disease which is generally held throughout the affected district that the rain is the real cause, the idea was hit upon of tying covers over the bunches so as to protect them from the rain. Just where this idea originated is hard to say but it is practised throughout the affected parts of Mysore and apparently also in the Canaras while in Malabar and Cochin it is unknown. The custom seems to date back a goodly number of years and I have been unable to obtain any accurate information as to when it started.

These coverings are made of the basal sheaths of the huge leaves. They are collected as they drop from the trees and are hung over poles so as to allow them to dry out. The covers are made in two different ways as shown by accompanying figures.

In the northern part of the affected district a leaf-sheath is placed in the centre and on each side is sewed a half leaf sheath (made by splitting a sheath longitudinally). The whole is then wrapped about the growing bunch as is shown in text-figure 2.

Farther south but within 30 miles of localities where the above described form is used the covering is quite differently constructed. Here one sheath is placed on top and a second is sewed across the end and then folded along each side so as to form a bonnet-like covering as shown in text-figure 3.

Each type has its particular advantages and disadvantages. In the case of the first while the sides of the bunch are well protected the end is not. And if the bunch is situated close to the stem the result is that the open end is directed vertically and so serves to catch the water rather than to keep it off. The second type on the other hand has more of a roof-like nature but frequently leaves the sides of the bunch exposed. In both cases there is considerable danger of dislodgement or tearing or even rotting of the covering during the fierce winds and heavy rains of the month of July so that though these coverings are fairly effective they leave much to be desired. In order to be at all effective the tying must be done early and before the disease appears. Once the disease has appeared on a bunch no amount of tying of covers will save it. In fact the disease may under certain conditions be favored rather than checked by the coverings. Careful observations made show that even where coverings have been tied early and have remained intact and in place, the disease is capable of spreading although not so rapidly. In one garden observed the appearance of the disease within four days on forty trees practically all of which had coverings, was noted. In another case a spread over 8 trees took place within 3 days. Moreover the tying of coverings hardly allows of being carried out as extensively as it should for a serious campaign against the disease. In a given garden it would hardly be possible to collect sheaths sufficient to make coverings for more than a fraction of the trees and the importation of them from outside tracts would make them decidedly too expensive. To make this clear one need only consider that each leaf sheath fallen represents a bunch which has developed at its base. So should all the bunches come to maturity and all the sheaths be saved for the purpose of making coverings there would be sufficient sheaths to make coverings for just half the number of bunches. Neither of these suppositions finds itself actualised as a number of bunches always fail to mature while on the other hand many sheaths are split on dropping or rot before being picked up. There

are, moreover, a hundred and one other uses to which these sheaths are put, such as the making of roofs, of plates etc.

The usual custom is for the garden owners to wait till the disease has appeared, if not in their own gardens, in the garden of their neighbourhood, before tying the covers on the bunches.

The fact that these coverings were so likely to break led to the idea of making covers of tin. A few of these were tied experimentally but evidently did not prove a success. The garden owners in the neighbourhood where they had been used stated that such coverings cut or otherwise injured the bunches during the heavy rains and on the other hand on days of bright sun-shine the nuts were almost baked beneath the covers. In any case it appears doubtful whether such covers would be a material improvement over those at present in use.

Fig. 4.

It seemed to me early in the investigation that spraying with Bordeaux mixture might prove successful, the great difficulty of course being that of getting the spray to the bunches as these are anywhere from 50—70 feet above the ground. One point in its favor was the fact that the people were already engaged in a combative measure which required them to climb the trees and tie a cover on each individual bunch.

The first spraying experiments were carried out with a large barrel sprayer on wheels and a long line of woven pipe to reach to the top of the trees. The great difficulty experienced was that of moving a heavy barrel sprayer about in the gardens which have deep drainage ditches running between each two rows of trees and which moreover are frequently thickly planted with plantains or bananas (*Musa* sp.). It was then decided to use a small sprayer to be worked by compressed air and to hold about a gallon of fluid. A sprayer suited excellently to these requirements is the small „Pekrunspritze“ manufactured by Gebrüder Holder in Metzingen. It was fitted into a sort of harness made of canvass and the whole was slung over the climbers' shoulders. Both hands were thus free to pull over and tie trees together, direct the spray etc. It

was found that with such a sprayer a climber could treat the trees in about one third of the time it took for tying covers. By means of the jet spray even the highest trees where it was too dangerous to tie covers could be reached.

The climbers do not of course climb each individual tree but jump from tree to tree and they seemed to experience no difficulty in doing so with a small sprayer on their backs any more than with a bundle of covers which they have to carry. The spray can be localised on the bunches of nuts so that a very small quantity is required to spray an acre of garden. Careful estimates indicate that such spraying can be done at a cost of approximately Rs.3/— per acre.

The results of a year's spraying have been carefully collected and are to be published shortly in a bulletin of the Mysore Agricultural Department. Bordeaux mixture of the socalled 5-5-50 formula was used but in most cases double strength. In addition an adhesive was used consisting of 2 lbs of resin and 1 lb of washing soda boiled in 1 gallon of water. This was added to 25 gallons or 50 gallons of the mixture as the case may be. The results summarised indicate that a single application made early in June just before the monsoon with adhesive at the rate of 1 gallon to 25 gallons of the Bordeaux mixture is more effective than the coverings used. In most cases the difference was fairly marked. An adhesive of half the strength (i. e. 1 gallon to 50 of the mixture or in another case 1 lb resin instead of 2 and 1 lb soda in 1 gallon of water) did not give nearly as good results. With the strong adhesive it appeared to be immaterial whether the 5-5-50 or the 5-5-25 formula for the Bordeaux mixture was used. This point however requires further investigation.

The difficulties to be contended with in spraying bunches on Areca palms would make it very difficult to persuade garden owners to do more than one spraying in a season and therefore only single spray experiments were carried out. Attention is to be directed this year to the testing of adhesives as it is in this direction alone that spraying areca bunches in Mysore can be made more efficient without becoming too expensive and trouble some for the garden owners, who are of course all natives.

Another question of practical importance that will claim attention is the question of alternate hosts for the Areca fungus in the gardens. Up to the present none have been noted but attention has not been directed as closely to this point as it will be in the future*).

*) Since the above was written an article by Petch in the Tropical Agriculturist of May 1910 has brought to my notice the fact that the Cacao fungus has already been given the name of *Phytophthora Faberi*. Mr. Petch has kindly furnished me with the reference to the article containing the description. Maublanc who has continued Delacroix's articles on „Les maladies des Plantes cultivées dans les Pays

chauds“ in „L'Agriculture pratique des Pays chauds“ has apparently without any examination of the fungus, erected a new species on von Faber's description. The following is the description kindly furnished me by Mr. Petch from „L'Agriculture pratique des Pays Chauds“, No. 79, 1909, P. 315. „*Phytophthora Faberi*, nov. sp. Taches irrégulières, brunes; spores blanc ou jaunâtre peu visible; conidiophores longs de 150 à 200 μ, continus, hyalines et terminés par une conidie apicale, plus rarement, rameux et portant 2 conidies; conidies (sporanges) de forme variée généralement en citron, à membrane mince, lisse un peu épaissie au sommet 30—80 × 25—42 μ; oospores arrondies lisses à membrane épaisse, 45 μ de diamètre.

Parasite sur les fruits du Cacaoyer dans les régions chaudes.

Distinct du *Phytophthora cactorum* (Cohn et Leb.) Schr. par la dimension des oospores et le moins grand nombre des zoospores produites à la germination des conidies.“

It will be seen on a comparison with von Faber's paper that Maublanc adheres almost exactly to his description. Although von Faber did not feel justified in erecting a new species on the data he had collected that in no way deters Maublanc. As to the name it is naturally immaterial which of the two names should be given to the fungus although it seems to me a somewhat unusual and questionable thing to do,— to establish a new species on another author's description especially when that author expresses himself with exemplary caution as von Faber has done in his paper.

Explanation of Plates VII to IX.

Plate VII. Fig. I. Bunch of Areca-nuts affected by Koleroga. Many of the nuts from the left side of the bunch have already dropped off and nuts scattered throughout the bunch are attacked by the disease. The dead male flower branches are to be seen as brownish filaments.

Fig. II. Branch from affected bunch showing one healthy and one diseased nut. Two male flower branches are also to be seen.

Fig. III. Areca-nut showing the first symptoms of the disease. The more darkly colored areas reaching upward from the base of the nut mark the places where the fungus will first break forth on to the surface.

Plate VIII. Diseased apex of Areca stem split lengthwise to show infection through the diseased bunch-stalk.

Plate IX. Diseased apex of Areca stem split lengthwise to show infection through the bases of the leaf-sheaths.

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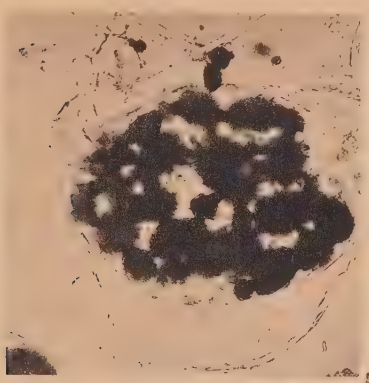

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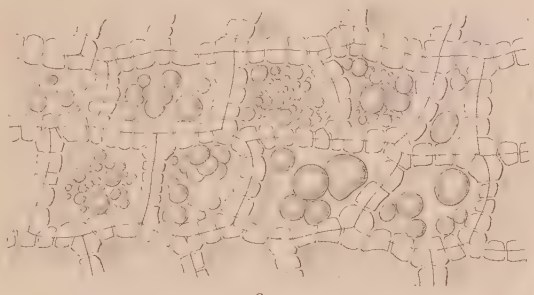

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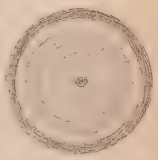

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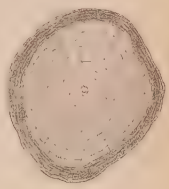

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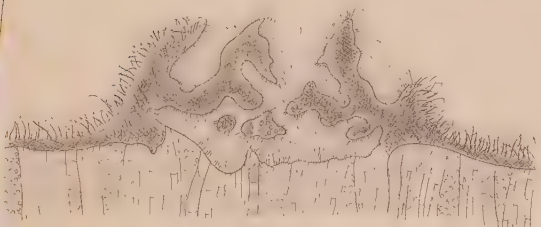

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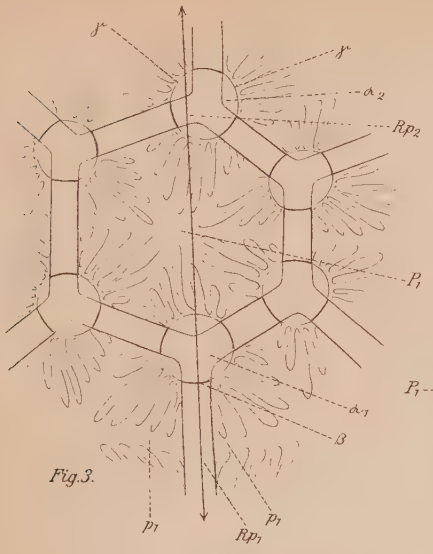

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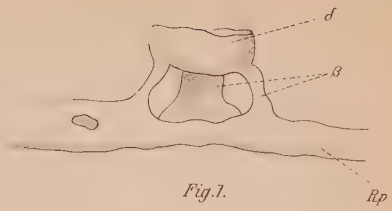

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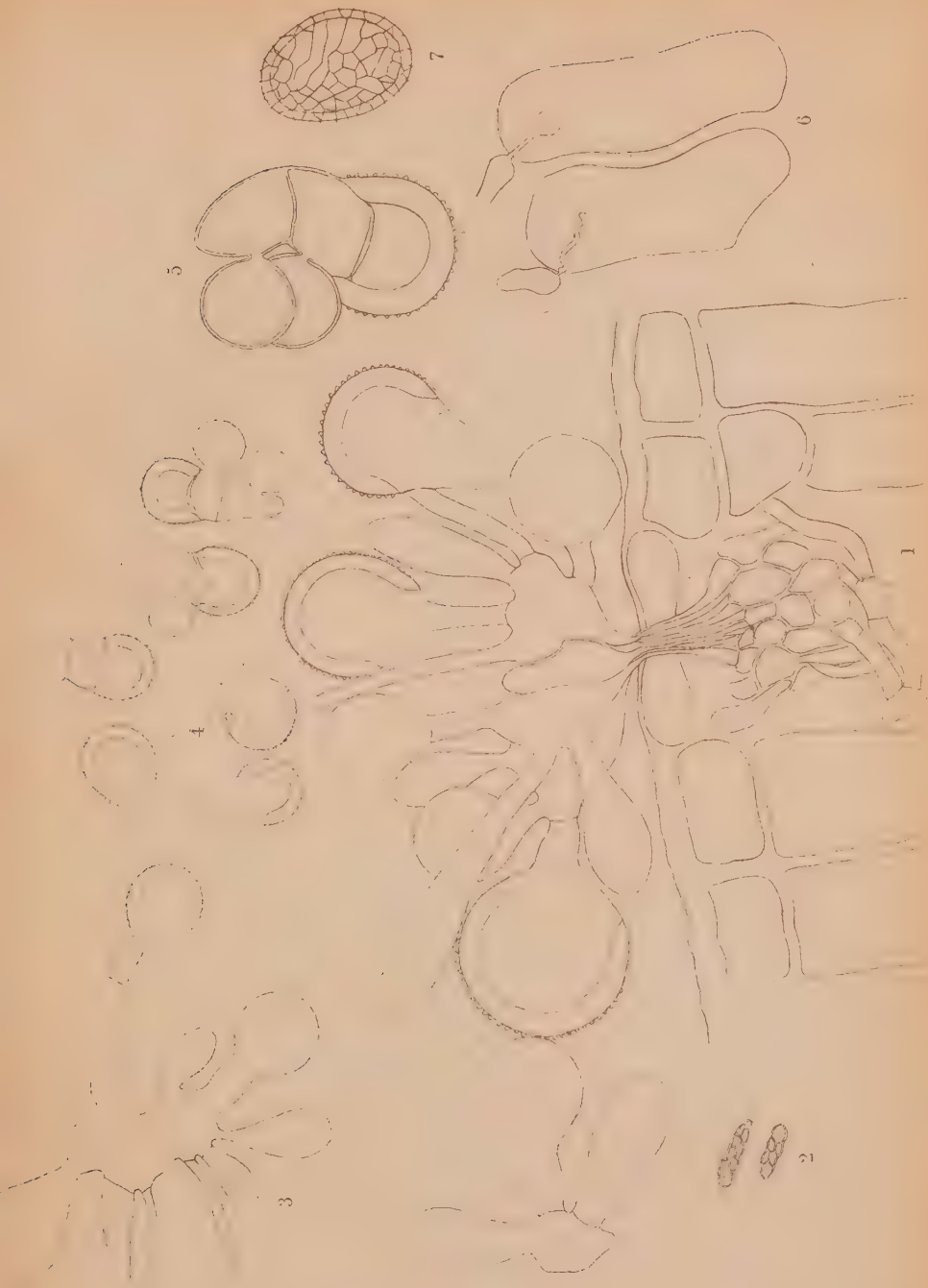

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